WATER INFUSION TECHNOLOGY FOR DUST CONTROL

ON LONGWALL FACES IN THE SYDNEY COALFIELD

BY

NORWEST RESOURCE CONSULTANTS LTD.

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EXECUTIVE SUMMARY

Water infusion has been used to control dust in many coal mines in Europe, the U.S.A., and Australia. The effectiveness of water infusion at a specific site has been shown to be constrained by the physical characteristics of the coal, the geological environment of the coal seam, the effects of methane gas and the accessibility of the coal seam. Consequently equipment and procedures for infusion have been designed to suit a wide variety of coals, environments and operating circumstances.

Mining in the Sydney Coalfield by retreat longwalls or advancing longwalls presents two distinct sets of operating circumstances in which to accommodate the water infusion procedure. Retreat mining at the Prince Mine will permit infusion through long holes drilled parallel to the face from the head and tail roads well in advance of mining without interrupting the production cycle. Advance mining at the Lingan Colliery will permit the use of holes drilled from the face or gate ends, with consequent potential for interruption of production. Long hole infusion from the adjacent road may be feasible at the Lingan Colliery.

Water infusion techniques may be grouped according to the geometry of the installations, length of holes and water pressures employed. Mine and panel geometry constrain the selection of water infusion systems and it is therefore useful to categorize infusion techniques by their geometry.

In the simplest example holes are drilled straight ahead from the face to a depth approximately 0.5 m greater than the daily advance. Water is infused through the holes for either the time available between cutting shifts or some time determined by experience to be appropriate. The pressure under which the infusion water is introduced varies substantially between operations but the limited time available for infusion generally requires high infusion pressures to provide the necessary quantity of water.

Holes for infusion can be drilled parallel to the face in retreat longwall panels and in some advancing panels where headings are maintained ahead of the face. In retreat mining, infusion from the roads can commence at any position in front of the face and it has been shown that long term, low pressure infusion, sometimes called continuous infusion, is effective in introducing sufficient water into the coal to suppress dust at the face.

Implementation of successful water infusion will not eliminate the need for conventional dust suppression at the face and in the coal handling system but may effectively lower the levels of respirable dust when implemented as a complementary suppression technique.

Methane production from a mine district will not be affected by water infusion but some change in the distribution of methane flow patterns within districts may be expected as a result of infusion.

Pressures at which infusion is commonly conducted vary from the mine water system pressure (typically up to 2,000 kPa) to very high pressure delivered by infusion pumps (up to 50,000 kPa). The infusion probes and method of hole sealing should be selected to accommodate the desired pressure.

Infusion from the roads ahead of a retreating face has been successfully accomplished in France at 1,500 to 3,000 kPa pressure with flow rates as low as 0.5 to 3.0 l/min over periods of 2 to 3 months. French experience with infusion from the face indicates that pressures from 8,000 to 10,000 kPa should be used to provide sufficient water in the available time. Studies carried out in Germany indicate that for infusion from the face, flow rate of up to 80 l/min are obtained at pressures up to 35,000 kPa, the infused water amounting to approximately 10 l/m^3 of coal at which level satisfactory dust suppression can be obtained.

The drills identified in the literature as being suitable for water infusion holes are generally those machines which are in use for other purposes in the collieries concerned.

Infusion is conducted with water which may contain additives to modify the wetting capability or evaporation rate of the infused water. The indiscriminate use of surfactants should be avoided as they can adversely effect infusion if improperly applied.

Control systems for infusion using the mine water supply pressure have been developed in France. The objective of these systems is to allow monitoring and regulation of the rate of infusion and to provide automatic shut down if accidental water leakage occurs during periods when the mine is not fully manned.

Short hole infusion has been carried out using mechanical hole packers (screw type), pneumatic and hydraulic packers and self inflating hydraulic packers. Only self inflating hydraulic packers are commonly in use today. They consist essentially of a high pressure reinforced hose which is designed to expand diametrically under pressure. At the completion of infusion the water supply is shut off, the probe deflates and can be easily removed.

Long holes for infusion from the roads are commonly sealed using cement grouts. Many different methods of applying cement seals have been reported but all have the same objective which is to provide a cheap easy to install seal which is effective over the lifetime of the infusion process.

The use of resin sealing materials, similar to the resin grout used for rock bolting, has been proposed for water infusion. These materials are expensive and difficult to apply in long holes where pumps must be used. Generally speaking a portland cement grout applied with simple equipment will perform very efficiently and is preferrable to costly resins or inflatable packers for long hole, long term infusion.

Operating aspects of water infusion vary from mine to mine and often from face to face within the same colliery. It is vital on modern, high productivity faces to integrate the infusion process with all other operating functions to prevent interference with face productivity. Integration of water infusion with coal winning operations is more complicated for infusion from the face than for infusion from the roads.

The equipment requirements for infusion from the face are greater than for infusion from the roads, this together with the much higher level of manpower used per metre of advance, will tend to make face infusion more costly than infusion from the roads. The manpower cost for face infusion may be approximately twice that for infsuion from the roads.

Dust reduction due to water infusion has been reported at up to 70% in some cases. Almost all reported instances of water infusion have resulted in some beneficial reduction in dust concentrations.

The long term objective of successful water infusion is to reduce the amount of respirable dust to which the miner is exposed. In conjunction with conventional dust suppression measures, water infusion may provide a substantial benefit in this regard and help eliminate a major safety hazard.

Three case studies are presented which report water infusion tests and results in British and American collieries. The technology employed in the British examples was basically French or German in origin with some modification to suit local conditions.

The Sydney Coalfield is a virgin area as far as water infusion is concerned. Almost no firm data exist upon which to begin to evaluate the infusibility of the coal, there is an absence of data regarding the sources of dust at the face and the effects of moisture on the structural integrity of the roof and floor remain to be examined. A comprehensive program of research

and development is required to provide basic information which could lead to substantial reductions in the hazard from dust.

Examination and analysis of the existing conditions in the workings should preceed detailed laboratory and in situ testing of water infusion. In situ testing will be required to estimate appropriate pressures and flow rates.

It is possible that an entire set of infusion equipment could be purchased from foreign sources and successfully applied in the Sydney coalfield. This approach is regarded as unsatisfactory if in the long run the intention is to apply water infusion in several new mines. The differences in infusion characteristics from seam to seam and even from face to face would indicate that for widespread success, there should be a concentrated effort to develop Canadian expertise in the field.

SOMMAIRE

Dans plusieurs mines de charbon d'Europe, des Etats-Unis et d'Australie l'infusion d'eau est un moyen de prévention technique des poussières. Il a été démontré que son efficacité à un endroit précis a été gêné par les characteristiques physiques du charbon, l'environnement géologique d'une couche de charbon, les effets du méthane et l'accessibilité d'une couche de charbon. Par conséquent, l'équipement et les méthodes pour l'infusion d'eau varient afin d'accommoder les différents types de charbon, les différents milieux et les différentes méthodes d'exploitation.

Dans le champ de charbon de Sydney, l'exploitation minière par longues tailles rabattantes ou par tailles avancantes chassantes représente deux moyens ditincts d'exploitation auxquels on peut adapter le prodédé d'infusion d'eau. L'exploitation rabattante à la mine Prince nécessitera l'infusion par de longs trous forés parallèlement à la taille à partir des voies de tête et de base, et cela bien en avance de l'exploitation évitant ainsi des interruptions de travail. L'exploitation avancante à la mine Lingan nécessitera l'emploi de trous forés à partir de la taille ou de la galerie ce qui pourrait entraîner des arrêts de travail. L'infusion par de longs trous à partir des voies adjacentes est peut-être faisable à la mine Lingan.

Les techniques d'infusion d'eau peuvent être groupées selon la géometrie des installations, la longueur des trous et les pressions d'eau utilisées. La géometrie de la mine et des chambres restreint le choix d'un système d'infusion d'eau. Il est donc utile de classifier les techniques d'infusion selon les géomètres de la fosse.

Dans l'exemple le plus simple, des trous sont fores au front de la taille jusqu'à une profondeur d'environ 0.5 m de plus que l'avance quotidienne de la taille. L'eau est infusée par les trous soit durant la période entre les changements d'équipes, soit durant une autre période que l'expérience a démontré appropriée. L'eau est introduite sous une pression qui varie

considérablement d'une mine à une autre; cependant parce que l'infusion doit se faire durant un temps limité, il faut que l'infusion se fasse sous une haute pression afin d'obtenir la quantité nécessaire d'eau.

Des trous pour l'infusion d'eau peuvent être forés parallèlement à la taille dans les chambres à longue taille rabattante et dans certaines chambres à taille avancante où les avancements sont maintenus à l'avant de la taille. Dans les exploitations rabattantes, l'infusion à partir des voies peut commencer n'importe où à partir du front de taille, et il a été démontré qu'une infusion d'eau continue, à faible débit, appelée quelquefois infusion permanente, introduit suffisamment d'eau dans le charbon pur permettre la suppression de la poussière à la taille.

La mise en oeuvre d'un système d'infusion d'eau n'éliminera pas la nécessité d'employer les méthodes traditionelles de suppression de poussières à la taille et dans le système d'exploitation du gisement. Toutefois, l'infusion peut réduire effectivement les niveaux de poussières respirables quand ce système est mis en oeuvre en tant que technique de suppresion complémentaire.

Bien que dans un district minier, la production du méthane (grisou) ne soit pas affectée par l'infusion d'eau, il se peut qu'il y ait quelque changement dans la distribution des modèles d'écoulement du méthane à l'intérieur des districts.

L'infusion se fait sous des pressions allant de la pression de la circulation d'eau de la mine (habituellement jusqu'à 2000 kPa) aux pressions très hautes que donnent un pulvérisateur (jusqu'à 50,000 kPa). Les sondes d'infusion et les méthodes d'étanchéite des trous devraient être choisies dans le but d'obtenir la pression désirée.

L'infusion à partir des voies à l'avant d'une taille rabattante a été accomplie avec succès en France à une pression de 1500 à 3000 kPa avec un débit aussi bas que 0.5 à 3.0 litres/minute durant une période de 2 à 3 mois.

L'expérience française démontre que des pressions de 8,000 à 10,000 kPa devraient être utilisées pour obtenir l'eau nécessaire dans le temps disponible. Pour une infusion partir de la taille, des études faites en Allemagne montrent que si on obtient un débit de 80 litres/minute à des pressions allant jusqu'à 35000 kPa, l'eau infusée totalise à peu près 10 litres/m^3 de charbon, soit un niveau permettant une suppression satisfaisante de la poussière.

Les foreuses indiquées dans la documentation comme convenant à l'infusion d'eau sont généralement celles qui sont déjà utilisées pour d'autres usages dans les mines concernées.

L'infusion se fait avec de l'eau qui peut contenir des additifs visant à modifier les effets mouillants ou le taux d'évaporation de l'eau infusée. L'usage aveugle des additifs devraient être évité puisqu'ils peuvent avoir des effets défavorables sur l'infusion s'ils ne sont pas bien utilisés.

Pour l'infusion employant la pression de l'approvisionnement d'eau de la mine, des systèmes de contrôle ont été développés en France. Ces systèmes ont pour but de surveiller et de régulariser le débit d'eau et d'assurer une fermeture automatique dans le cas où une fuite d'eau se produirait accidentellement durant une période où le personnel ne serait pas au complet.

L'infusion à partir de trous courts peut se faire en utilisant des bouchons percés mécaniques (du type d'une vis), des bouchons pneumatiques et hydrauliques et des bouchons hydrauliques qui se gonflent d'eux-mêmes. Seulement ces derniers sont en usage aujourd'hui. Ils consistent essentiellement d'un tuyau réenforcé à forte pression qui est conçu d'une telle façon qu'il va se dilater sous pression. Quand l'infusion d'eau est terminée, l'approvisionnement d'eau est fermé, les sondes se dégonflent et peuvent être facilement enlevées.

Les trous longs utilisés dans l'infusion à partir des voies sont généralement rendus étanches par un remplissage de lait de ciment. Il existe plusieurs

moyens d'appliquer les remplissages de ciment et ils ont tous le même but, celui d'obtenir un remplissage bon marche et facile à installer, qui sera effectif durant toute la durée du procédé d'infusion.

L'emploi de matériaux d'étanchéite résineux, semblables à ceux utilisés pour les soutènements par boulons d'ancrage, a été proposé pour l'infusion d'eau. Ces matériaux sont coûteux et difficiles à appliquer dans les trous où les pompes doivent être employées. En général, les remplissages de lait de ciment appliqués avec un équipment simple s'avèrera très efficace et préférable à des matériaux résineux dispendieux ou à des bouchons gonflables en ce qui a trait aux trous longs et à l'infusion à long terme.

Le fonctionnement de l'infusion varie d'une mine à l'autre et souvent d'une taille à l'autre à l'intérieur d'une même mine. Il est vital que dans les tailles modernes, à haute production, le procédé d'infusion soit integré à tous les autres aspects de l'exploitation, et ce afin que l'infusion ne gêne en rien la production de la taille. L'intégration de l'infusion d'eau à la production du charbon devient plus compliquée quand l'infusion doit être faite à partir de la taille plutôt qu'à partir des voies.

Cette dernière nécessite plus d'équipements. Elle demande aussi un accroissement de la main-d'oeuvre pour chaque mètre de progrès. Le coût de la main-d'oeuvre pour l'infusion à partir de la taille peut être le double de celui pour l'infusion à partir des voies.

Le taux de réduction de la poussière attribuable à l'infusion d'eau est de 70% dans certains cas. Presque toutes les expériences d'infusion documentées montrent une certaine réduction avantageuse des concentrations des poussières.

Le but à long terme de l'infusion d'eau est de réduire le montant de poussières respirables auxquelles le mineur est exposé. Conjointement avec les méthodes traditionelles de suppression de la poussière, l'infusion d'eau offre une

dimunition considérable de la poussière et contribue ainsi à éliminer un danger majeur de sécurtié.

Trois cas-types sont présentés dans ce rapport. Ils décrivent les tests et les résultats de l'infusion d'eau dans les mines de charbon de Grande-Bretagne et des Etats-Unis. La technologie employée en Grande-Bretagne est fondamentalement française ou allemande mais elle a été adaptée aux conditions locales.

Le champ de charbon de Sydney est un terrain vierge en ce qui concerne l'infusion d'eau. Il n'existe à peu près pas d'information solide qui permettraint d'évaluer la perméabilité du charbon. Il n'y a pas d'information en ce qui a trait aux sources de poussières dans les tailles et les effets de l'humidité sur la structure du toit et du plancher sont encore à examiner. Un programme comprehénsif de recherche et de devéloppement est nécessaire afin d'obtenir de l'information de base qui pourrait mener à une réduction considérable des dangers résultants de la poussière.

L'étude et l'analyse des conditions existantes dans les milieux de travail devraient précéder les tests en laboratoire et sur place. Les tests d'infusion sur place seront nécessaires pour estimer les pressions et les débits appropriés.

Il est possible qu'un ensemble complet d'équipment à infusion puisse être acheté à l'étranger et employé avec succès dans le champe de charbon de Sydney. Cette manière de faire laisserait à désirer si le résultat recherché est l'application de l'infusion d'eau dans plusieurs mines nouvelles. Les différentes caractéristiques de l'infusion d'une couche à l'autre ou même d'une taille à l'autre semble indiquer que pour l'obtention d'un meilleur succès, un effort concentré en vue de développer une technique canadienne en ce domaine est à encourager.

SECTION 2

GEOLOGICAL CONSIDERATIONS

The information contained in this section of the report describes features of the geology of a coalfield that have a significant impact on the application of water infusion techniques. These features described include porosity and permeability considerations for the roof, seam, and the floor strata, and the impact of both structural and stratigraphic features.

The subsequent discussion shows the relationships between these geological factors and conditions that are actually known to exist in the seams of the Sydney Coalfield.

2.1 GEOLOGICAL FACTORS AFFECTING INFUSIBILITY

2.1.1 Introduction

The geological factors that have an effect on the application of water infusion technology as a means for methane and dust control are all those which affect the rate at which water or equivalent fluids can be injected into a coal seam, which affect the degree to which those fludis are dispersed within the coal, which affect the loss of fluids into the surrounding strata and which affect the integrity of the roof and floor strata as supporting structures for underground mining operations.

2.1.2 Porosity

The migration of water based fluids is influenced most strongly by the coal's fracture density and geometry. Although intact coal has a measurable porosity, the size of the pore spaces (generally about 5 angstroms) is too small to provide for significant transmission of fluids; the effective porosity is the fracture porosity of a coal seam. In the majority of cases there is

a tendency for all naturally occurring fractures in coal to be referred to as cleat unless measurable displacements are detected which define specific fractures as faults. The term cleat is simply the name used for joints occurring in coal and the formation of a cleat is believed to be produced by exactly the same factors which produce joints in the surrounding strata. The geometry of any cleat pattern is consistent with the equivalent joint pattern in the surrounding strata, with the exception that the mechanical properties of coal are different from those of most other soft sediments. This factor can produce apparent differences between equivalent cleat and joint sets. Usually the most apparent difference between equivalent cleat and joint sets appears as significant differences in the fracture density.

On occasion fractures are found in coal seams which do not appear to be related to the patterns of jointing observed in the surrounding strata. These coal fractures may be related to a locally developed fracture system in the surrounding rock that does not technically qualify as a joint system. In other cases there may appear to be no direct equivalent to this coal fracture system in the surrounding rocks. Usually the geometrey of these coal fractues indicates a direct relationship to specific events of deformation resulting from tectonic events or differential compaction. Present concepts for the production of joints does not allow these coal fractures to be classified as a cleat. Fracture systems such as this do however contribute to the overall fracture porosity of a coal seam.

Based on investigations of jointing and cleats in eastern and western U.S. coalfields, McCulloch, et al (1974) concluded that:

"Cleat in the bituminous coalbeds studied is formed by local structural forces rather than by interal forces within the coal such as result during diagenesis and compaction. The face cleats tend to be perpendicular to the axial trend of the folds and probably formed as extension fractures. The butt cleats tend to be parallel to the axial trend and formed after compressive forces were released."

An elaborate discussion of the theoretical considerations for the formation and frequency of joints in rocks of different thickness and lithology and which display differing amounts of tectonic deformation is presented by Price (1966). The extent to which is pore water pressure may affect the development of those fractures is discussed by Secor (1965).

The face cleat is a system of extension fractures formed after structural deformation. Commonly the face cleat shifts orientation to maintain a perpendicular relationship to the axial trend of local structures. Fractures are generally more developed and are generally laterally more continuous and more frequent than the butt cleat. It is a system of release fractures formed during process of uplift and crustal extension. The butt cleat is generally the short, discontinuous, and may terminate against the face cleat. The face cleat is more likely to cross bedding planes within the seam.

In most reported investigations of cleat that address coalfields subject to only minor folding the face and butt cleat have an approximately perpendicular relationship to each other.

Numerous field studies have shown that the frequency of face or butt cleat development is related to the mechanical properties of the seam and its contained plies. A discussion of the theoretical considerations pertinent to this feature is provided by Price (1966). General observations from numerous seam exposures show that the change of frequency of either face or butt cleat is easily seen in coals of varying lithotype; bright bands of coal tend to have a much higher cleat frequency than do lithotypes that appear more dull. A striking example is reported by Macrae and Lawson (1954), who observed that for several seams in the Yorkshire coalfield durain bands thicker than six inches have less than five fractures per foot, whereas clean, bright coal bands ahve 70 fractures per foot. It is important to realize, therfore, that while the frequency of the face cleat and butt cleat may vary significantly in any one coal type, changes from one lithotype to another tend to produce proportionally greater changes in both the face and butt cleat.

The preceeding discussion indicates that the fracture porosity will vary with the lateral extent of any cleat surface and the frequency of those cleat surfaces. It also indicates that the fracture porosity will be greater in coals that display a high proportion of bright coal plies.

2.1.3 Permeability

The permeability of a coal seam subjected to the infusion of water based fluids is influenced by the fracture geometry. The nature of the face and butt cleat suggests that a lateral asymmetry exists due to differences in the lateral extent and frequency of fractures in each cleat system. This condition applies to some extent in all cases, but has less influence on considerations of water infusion where coal seams have a particularly friable character (Figure 2-1).

The fracture permeability of coal is an important factor influencing water infusion techniques. In many coal seams a preferential direction of fluid flow exists within the seam (Figure 2-2). This directional permeability or permeability anisotropy is directly related to different character of the face and butt cleat. The face cleat is usually the more permeable fracture system because individual fractures have a greater lateral extent and because there tends to be a higher frequency of face cleat planes than butt cleat planes.

2.1.4 Rock Bands

Several reported case histories indicate that the presence of rock bands and their permeability has a significant impact on the application of water infusion. Field studies conducted in many coalfields suggest that the majority of in seam rock bands have a high clay content and therefore their inherent permeability is relatively low. Fluids injected in the infusion process into one ply of a seam will be transmitted across a rock band and into another ply via naturally occurring fractures within the rock band. Most of the

naturally occurring fractues in rock bands are joints and these usually have the same geometrical relationships as do the cleat planes of the adjacent coal plies. The frequency of the joint planes, however, is almost always far lower than the frequency of cleat planes. Therefore it is reasonable to anticipate that although infusion fluids are able to move from one ply to another across a rock band the rate of transmission will tend to be retarded when compared with the vertical transmission of fluids in any one coal ply. The rate of horizontal transmission of fluids in a coal ply will normally exceed by a significant amount the equivalent rate of transmission of fluids vertically through a coal seam that contains one or more clay based rock bands.

It has been found that infused water tends to percolate to and accummulate in structural hollows or depressions that occur ahead of the coal face. This leads to difficult working conditions and the requirement for pumping when mining activities reach the location of those depressions. In the No. 20 Mine at Carbon, West Virginia, the infusion process was applied to one of the uppermost plies of the Big Eagle Seam which contained a rock band of the type described above (Cobb, 1969). The results obtained by infusion in this case were found to be more successful and it is believed that the presence of the rock band aided the process by reducing the potential for the less desirable consequences of rapid downward percolation within the seam.

2.1.5 Roof Strata

Although there are numerous examples to the contrary, the general environment of deposition for coal and its overlying strata suggests that the immediate roof materials tend to be composed of a high proportion of clay minerals. As in the transmission of fluids across clay rock bands it is anticipated that fluids infused under pressure will tend to penetrate through the roof strata mainly via joints and other naturally occurring fractures. Whenever this condition exists there will be a tendency for the fluids to

penetrate laterally within the seam rather than to be dispersed within the overlying rocks. It is not anticipated that the injection of water by itself will cause a significant deterioration of the roof materials since the combination of water and air are requirements that can lead to progressive deterioration of clay rich strata. Careful examination of each case however will be required to determine the impact of the injection of fluids under pressure on the security of the roof as a sound mining structure.

Examples do exist where the immediate roof strata consist of rocks that are more permeable than those of the underlying coal seam. Such materials might include sandstone or conglomerate with a low matrix content and a relatively small amount of cementing material. It is reasonable to anticipate that water infusion will be less successful in these cases because of the tendency for fluids to more rapidly penetrate the overlying roof rocks.

2.1.6 Floor Strata

Much of the discussion regarding the impact of water infusion of roof strata equally applies to the floor. As noted previously the presence of depressions or hollows in the floor leads to uncomfortable working conditions as a result of excessive accummulations of water as well as potential delays to production through the need to pump the excess water from the working places. As the floor is exposed when the mining face advances the presence of this water together with air in the roadways and the abrasive action of traffic moving across the floor can lead to deterioration of the floor as a supporting structure, especially if the floor rocks contain any amount of expanding or mixed layer clays. Appropriate testing of the composition of the floor rocks, and indeed, the roof strata, is required to fully assess the impact of water infusion on the integrity of the supporting structures.

2.2 THE SYDNEY COALFIELD

2.2.1 Geological Setting

They Sydney Coalfield is located on the northeastern edge of Cape Breton Island in Nova, Scotia. A marine transgression has submerged most of the original intermontane basin leaving only a small landward expression. The extent of the submarine portion of the coalfield is not known but appears to be considerable. To the west and south, pre-Carboniferous rocks are present in highlands which probably represent the old positive source area of the basin. In the southwest, the basin has been faulted against Precambrian rocks with erosional remnants of Mississippian Hortan-Windsor Group in unconformable contact with the overlying Pennsylvannian sediments.

The Sydney Coalfield is considered to be a limnic depositional basin having no evidence of marine incursions during deposition. Clastic sedimentation in the gently subsiding basin was largely controlled by the river channels and their load capacity. Rapid lithologic changes occur between channels, levees and interdistributory troughs. It is apparent that the sediment supply was always sufficient to maintain the level of the flood plain above sea level. Deposition of the coal and the associated fluvio-lacustrine sediments took place in a flood plain or valley floor environment.

This type of environment allows for the development of thick, laterally extensive seams notwithstanding associated rapid lateral variations in interseam lithology. The coal seams themselves are excellent marker horizons.

The low gradient of this depositional environment permitted the development of an extensive meandering river system with channel anastomosis.

All the sedimentary strata in the area are assigned to the Pennsylvanian Morien Series of Late Westphalian C to possibly Stephanian age. The landward

expression of the Morien Series attains a maximum stratigraphic thickness of 1965 metres in the Glace Bay area and is transgressive to the northwest where it onlaps older strata.

The Morien Series can be subdivided into two major lithologic units. Below the Tracy seam, the lower half of the series is generally non-coalbearing and consists of a monotonous sequence of grey-brown sandstones colloquially known as the Millstone Grit. Three very thin coal seams occur near the top of this section. A transitional zone between the two units is present between the Tracy and Phalen seams. The lithology grades into the predominantly sandy shales and siltstones of the productive coal measure. Figure 2-3 is a composite stratigraphic section of the coal-bearing sequence, and Figure 2-4 is a correlation diagram for the Harbour Phalen interval in the Lingan area.

The landward expression of the coal measures is approximately 50 kilometres long, measured in a southeast to northwest direction, and attains a maximum width of 30.5 kilometres. The highest strata exposed on land occur just above the Point Aconi seam.

Above the Phalen seam, the section becomes increasingly fine-grained reaching a maximum silty shale content of 70% to 80% above the Harbour seam. In the off-shore region the section becomes essentially 100% silty claystone above the Murphy seam.

The specific interseam lithology varies considerably though the shale/sand ratio is remarkably uniform over the entire coalfield.

The tectonic development of the Sydney Coalfield has been very gentle with no serious structural problems occurring in the working areas. Only gentle folds are present which fan out seaward and trend in a general northeasterly direction. Minor thrust faulting is present and probably occurred as a response to orogenic movements during the Permo-Triassic.

Figure 2-5 illustrates the geological structure of the Sydney Coalfield.

2.2.2 Coal Seam Stratigraphy

Consistant with the geological environment, the coal seams appear to have great lateral continuity and relatively consistent thickness. The seams may be readily correlated between widely-spaced data points.

Only four seams are believed to reach a mineable thickness and their development has been traced across the region. These are listed Table 2.1 and described in the following paragraphs.

Phalen Seam

This seam, the lowest of the four under consideration, reaches a maximum thickness of 2.7 metres and averages 2.2 metres. The seam contains four characteristic bone bands lettered A to D from the base up (Figure 2-6) in the old Lingan Mine area. The lowermost of these, A, is only present to the west in the New Waterford area. Westwards from this area all four bands pass into thick shale partings leaving five unmineable benches of coal. Within the resource block area, of No. 26 Colliery, band A is not present. Bands B and C occur as a thin bone and a durain band, respectively. Band D develops into a stone parting. Figure 2-7 is a typcial seam section from the Lingan Phalen area. Towards the west the parting thickness rapidly, attaining 0.3 metres in the vicinity of the old Lingan Mine. The partings occur as a result of fluvial deposition of silt and clay within the peat bog.

Harbour Seam

The Harbour seam is one of the most consistent and best-developed seams in the Sydney Coalfield; shale partings are rare. Within the existing workings of No. 26 Colliery the seam maintains an average thickness of 2.0 to 2.25 metres. Isolated areas with thicknesses as high as 2.5 and as low as 1.8

metres have been recorded. In the Donkin Block thicknesses range from 2.8 to 3.6 metres. Changes in thickness apear to be fairly minor but have an irregular and variable distribution.

Four bone bands (Figure 2-5) with a characteristic petrographic composition are present and can be identified over the entire coalfield. The benches between these bands are not uniformly developed, with the result that sections of uniform thickness may not represent the same interval of peat deposition. Figure 2-8 is a fence diagram illustrating the correlation of coal and rock bands of the Harbour Seam in the Donkin-Morien development area.

Within the No. 26 Colliery area, the lowermost bone bands (A and B) are significant since they thicken to partings in excess of 0.6 metres. The lower two benches disappear into the pavement.

Hub Seam

The seam appears to be split into three benches with only one being considered thick enough to mine. The equivalent of these three benches appears to exist in the Prince Mine area (Figure 2-9). Analysis of the off-shore drill holes in the Donkin-Morien area (Figure 2-10) illustrates how variation in rock band thickness influences mining section. Within the reserve of No. 26 Colliery the thickness of this seam appears to be less than 1.6 metres. However, in the Donkin area the mineable coal, representing a portion of the seam, acheives a thickness of at least 2.7 metres.

Lloyd Cove Seam

Limited data is available on the development of this seam. In the eastern portion of No. 26 Colliery the seam has deteriorated to the point of being almost non-existent. In the Donkin reserve block estimates of thickness vary from 1.0 to 3.0 metres. The seam appears to occur in two benches with

a rock split which diminishes towards the west. A fence diagram illustrating the development of the seam in that area is included as Figure 2-11.

Roof and Floor Strata

Harbour Seam

In general, the roof of the Harbour seam throughout the present mine workings is composed of mudstone or shale, which may be silty in part. Siltstone and sandstone, both as discrete units or as interbedded and gradational units, are also present.

A potentially significant factor in the Harbour Seam is the effect of paleo-sandstone river channels. These have been investigated in considerable detail by CBDC geological staff (Forgeron, 1980).

The condition is illustrated in Figure 2-12. Linear sandstone bodies, generally trending in a northeasterly direction, exist in the roof strata of the Harbour seam and it is CBDC's contention that they represent river channels which traversed the region of coal deposition. They are similar in form to "washouts" observed in coal seams elsewhere, in that they cut into the upper part of the seam in some localities. Figure 2-13 is a schematic illustration of projected areas of sandstone roof throughout the coalfield (after Forgeron, 1980).

The sandstones are fine to medium-grained, quartz-lithic, and generally massive. Mica is present but not to the degree where bedding plane partings have developed.

The floor of the Harbour seam is composed of hard, dark grey shale, which exhibits fissility in some areas.

Phalen Seam

The roof strata of the Phalen seam are essentially similar to those of the Harbour seam. In the No. 26 Colliery resource area drill hole H-1A showed 4 metres of shale overlain by 5 metres of sandstone. H-2 showed 2 to 6 metres of shale, overlain by 3 to 6 metres of interbedded siltstone and shale, which was in turn overlain by 8 metres of bedded argillaceous and silty sandstone.

The Phalen seam floor is recorded in the two off-shore drill holes as being a hard shaley siltstone, carbonaceous in part.

Examination of cores containing gas or liquid hydrocarbons recovered from the off-shore holes indicates that, in the fine grained sandstones, the effective porosity has been almost elimated due to compaction and cementation. In that the mudstones and shales are finer grained and equally compacted, it can be expected that a similar condition will prevail. Some minor influence of water could be expected in association with the sandstone channel fills referred to above.

Hub Seam

Like the Harbour Seam, sandstone channels are known to occur in the roof of the Hub Seam. A figure illustrating the occurrence of these features and section illustrating lithologies of seam roof and floor strata in the Prince Mine area are shown on Figure 2-14.

Lloyd Cove

In general lithologies of the roof and floor strata of the Lloyd Cove Seam are consistent with those found adjacent to the underlying Hub Seam. There are, however, no significant reported occurrences of channel sandstones occurring within the roof of this seam.

2.2.3 Pertinent Structural Geology Factors

The major features of structual geology and structure contours on the base of the Harbour Seam have previously been ilustrated on Figure 2-4. As noted in Section 2.2.1 the most significant features of structural geology affecting the application of water infusion are the naturally occurring fractures within the seams and surrounding strata, namely cleats and joints. Only a limited amount of analysis of these features appears to have been completed within the Sydney Coalfield to the present time. The available data has been supplied by Mr. S. Forgeron and Mr. B. MacKenzie of CBDC who we gratefully acknowledge.

Figure 2-15 is an analysis of the trends of joints in strata of the Sydney Coalfield, and Figure 2-16 shows the trend of the principal cleat orientations within the Harbour Seam in the Sydney Coalfield.

Within the Harbour seam the cleat direction varies from south 59^{o} west to south 82^{o} west with the most prominent direction being south 68^{o} west. Only one data point in the Prince Mine area, for the Hub Seam is available and the principal cleat trend in this case is south 81^{o} west. No data are available for the Phalen or Lloyd Cove Seams. There is no available data concerning cleat frequency.

The orientations for joints displayed on Figure 2-15 refer to trends rather than strikes. The possibility exists for one or more of these trends to each represent one or more joint set because this technique of analysis does not accommodate the significant variation of dip that occurs for two joint sets that have the same strike. A more rigorous analysis of structural data would plot strike and dip data on stereograms, this would identify separate joint sets and allow proper analysis of the variation in orientation. This type of analysis is recommended in any situation where significant changes of the strike of bedding are found within an area of investigation. Significant changes of the orientation of bedding do occur within the Sydney coalfield.

Nevertheless it is possible to conclude from Figure 2-15 that three significant sets of joints occur. One of these sets appears to be dominant, from the point of view of frequency of data collection, with respect to the other two. This joint set usually trends in an easterly to east - northeasterly direction which is somewhat coincident with the trend of major fold axes throughout the coalfield.

Unfortunately there is no data available to determine whether the apparently dominant joint set is the equivalent set from one location to the next. With the limitation of available data two possibilities exist for this joint set. The most likely situation is that it represents longitudinal or bc-joints, it is less likely that the joint set is one component of a shear joint conjugate.

Figure 2-16 which illustrates the measured orientation of the principal cleat has, in general, a coincident orientation with the dominant joint set described abvove. Once again this cleat orientation tends to be approximately parallel to the general orientation of the main fold axes in the coalfield. It therefore appears that this cleat orientation is most likely equivalent to a longitudinal or bc-joint orientation. From the discussion included within Section 2.1 it is normal to expect the face cleat to be oriented approximately perpendicular to the general trend of the dominant folds in any area, hence parallel to the orientation of ac-joints. The butt cleat usually trends parallel to the trend of fold axes, hence parallel to the trend of bc-joints (Prince, 1966; McCulloch et al, 1974). This implies that the measured orientation represents a butt cleat. It is normal to experience, however, that the face cleat is the visually more dominant cleat set. Clearly a contradiction exists in this case. The structural analysis data available at present provides no information on the existence of any other orientations which almost certainly do exist and remain uninvestigated. Without the availability of a full and detailed analysis of the various structural features of the geology that documents the orientation, both strike and dip, of each fracture set and includes details that allow discrimination between different sets, and the frequency of planes in each set, it is not possible to draw definitive conclusions to classify the

observed features. Nevertheless it is apparent that the most obvious cleat orientation has been determined and it is assumed that this represents the direction of the highest fracture permeability within the Harbour Seam. The limited data available for the Hub Seam suggests that an equivalent condition will apply. It is anticipated through consideration of the mechanism for formation of joints and cleats that the same condition also exists in the other potentially minable seams.

2.2.4 Porosity and Permeability

Although they are by no means the only geological factors of significane to evaluating the potential for application of water infusion, porosity and permeability data are probably the most important information. As discussed in Section 2.1, fracture porosity and permeability of the coal and perhaps also for the roof, floor, and in seam rock bands are required to judge infusion potential. There is no data available for the Sydney coalfield concerning these parameters. Testing on samples and in situ would be required to compile a suitably accurate data base.

Porosity and permeability data concerning intact samples from roof, floor and seam lithologies can also be of assistance. No such data exists for the coal seams within the Sydney Coalfield, and only a limited amount of data is available for the roof and floor rocks. This data is derived from laboratory tested core samples and has not been related to in situ conditions.

Appendix B includes available porosity and permeability data for the Sydney Coalfield.

2.2.5 Infusion Potential Based on Geological Factors

Although there is a large data base available concerning the geology of the Sydney Coalfield, little of this material is applicable to an assessment of geological factors affecting infusion. Fracture porosity and permeability,

coal lithotypes, the presence of rock bands, the geometry of the seam at any on place, and roof and floor lithologies appear to be the most significant factors that affect water infusion.

No information is available concerning fracture porosity and permeability for the Sydney Coalfield, but there is available data concerning seam lithotypes, the presence of rock bands, and roof and floor lithologies. Any conclusions that are to be drawn regarding infusion potential for different seams at one location or the same seam at different locations must be drawn from this restricted data. Consequently any conclusions will be subject to a high level of uncertainty.

Previous studies indicate that a higher level of success in the application of water infusion has been achieved in coal seams that tend to be friable. This implies that there is the requirement for a relatively high frequency of closely spaced naturally occuring fractures. This condition occurs in seams that contain a relatively high proportion of bright lithotypes such as vitrain. Those seams that contain a high proportion of vitrain tend to have higher Hardgrove Indices, lower inherent mineral matter, and higher reflectance. Table 2.2 includes the data made available concerning these parameters for different seams of the Sydney Coalfield at different locations.

Although the data is extremely limited there appears to be a tendency for the relationships described above to exist in the Sydney Coalfield. However, the available data does not indicate any significant trends either laterally across the coalfield or vertically through the stratigraphic sequency at any location.

Some of the existing ease studies indicate that benefits may be derived on the application of water infusion to mine sections of seams that include rock bands. Although mining has been undertaken in seams in the Sydney Coalfield that included rock bands it is not known whether or not the characteristics of these bands would produce a significant benefit to a

practical water infusion test. It is not anticipated their presence in any test area would cause serious detrimental effects.

The infusion of water under pressure into coal seams of the Sydney Basin can be expected to have some detrimental effect on the security of the strata surrounding the seam. The extent to which this may have an effect is unknown, but it is reasonable to expect more difficulties to be encountered in conditions where roof support problems are presently experienced in the mining operations. Such difficulties have been experienced in those circumstances where channel sands in the roof approach or penetrate the top of the seam. It is posible that water infusion operations conducted at or near those locations will have a tendency to increase the difficulty of maintaining a secure roof.

TABLE 2.1

WATER INFUSION TECHNOLOGY FOR DUST CONTROL ON LONGWALL FACES

Sydney Coalfield Seam Sequence

Seam	Coal Interval Thickness (m)	Interseam Thickness (m)
Point Aconi	1.0 - 2.0	
		70 - 90
Lloyd Cove	10. - 3.0	
		60 - 70
Hub Zone *(1)	3.0 - 13.0	
		90 - 110
Harbour (2)	2.0 - 4.5	
		60 - 80
Bouthillier	0.5 - 1.0	
		20 - 40
Back Pit	0.5 - 1.0	
		30 - 35
Phalen (3)	0.5 - 2.0	
		40 - 60
Emery	0.5 - 1.5	
		130
Gardiner	0.5 1.5	
		330
Mullins	1.0 - 2.0	
		175
Tracey	1.0 - 2.0	

(After Haites, 1951; Forgeron, 1980; including Donkin-Morien data).

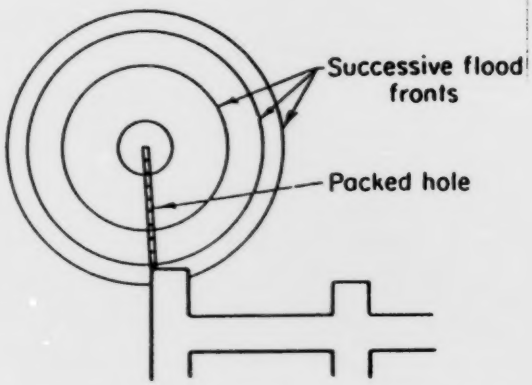
* May include up to 10 m of major rock partings

(1) Prince Mine and Donkin Morien Project (long term)
(2) Lingan and #26 Mines; Glace Bay and Donkin Morien Projects
(3) Lingan-Phalen and Glace Bay Projects

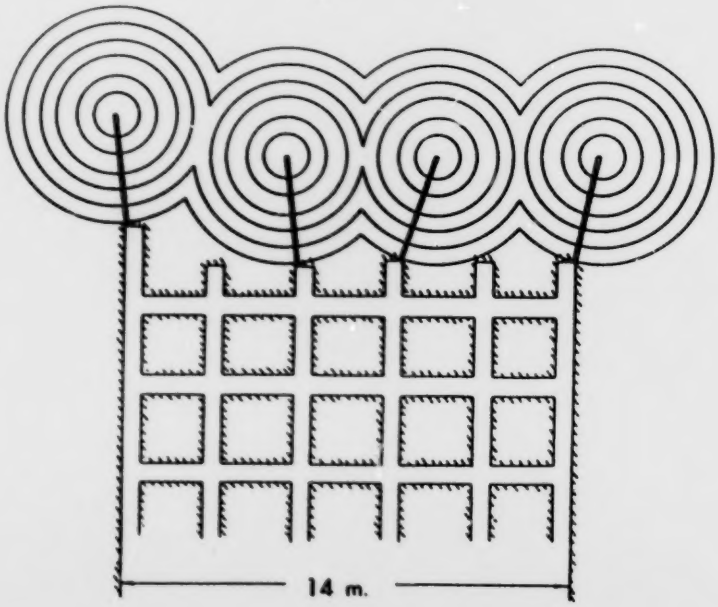
TABLE 2.2

SUMMARY OF COAL CHARACTERISTICS
SYDNEY COALFIELD

Resource Area	Seam	Clean Coal Ash	Reflectance	HGI
Donkin Morien	Lloyd Cove	8.6	0.93 (79.3)	64.3
	Hub	4.8	0.92 (81.8)	69.8
	Harbour	6.8	0.97 (80.5)	67.1
Glace Bay	Harbour	4.0	1.05 (83.5)(No. 26)	68 (No. 26)
	Hub		1.02 (84.0)	N/A
	Phalen	6.5	1.10 (79.0)	N/A
Lingan Phalen	Phalen	N/A	N/A	N/A
Lingan	Harbour	N/A	0.94 (78.1)	56
Prince	Hub	5.3	0.78 (82.8)	66.4



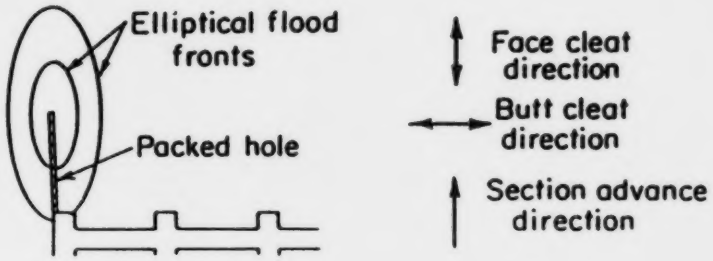
Completed infusion of one hole.



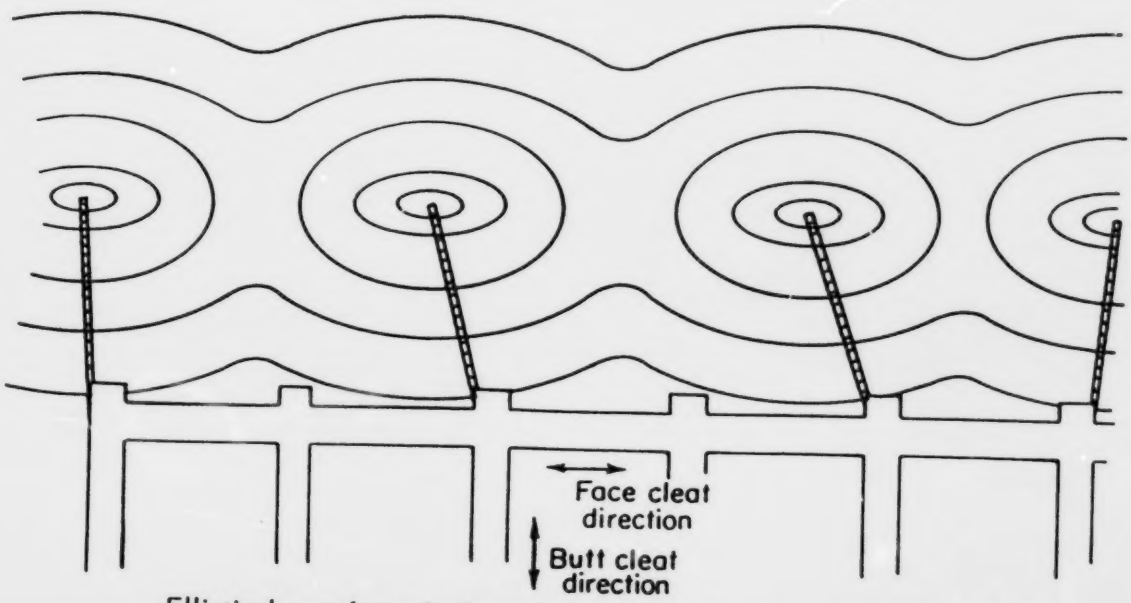
Water-infused section.

FIGURE 2-1

APPLICATION OF WATER INFUSION TO A FRIABLE COAL



Elliptical waterfronts for face cleat parallel to section advance direction.



Elliptical waterfronts for face cleat perpendicular to section advance direction.

FIGURE 2-2

APPLICATION OF WATER INFUSION TO A COAL SEAM WITH ANISOTROPIC FRACTURE PERMEABILITY

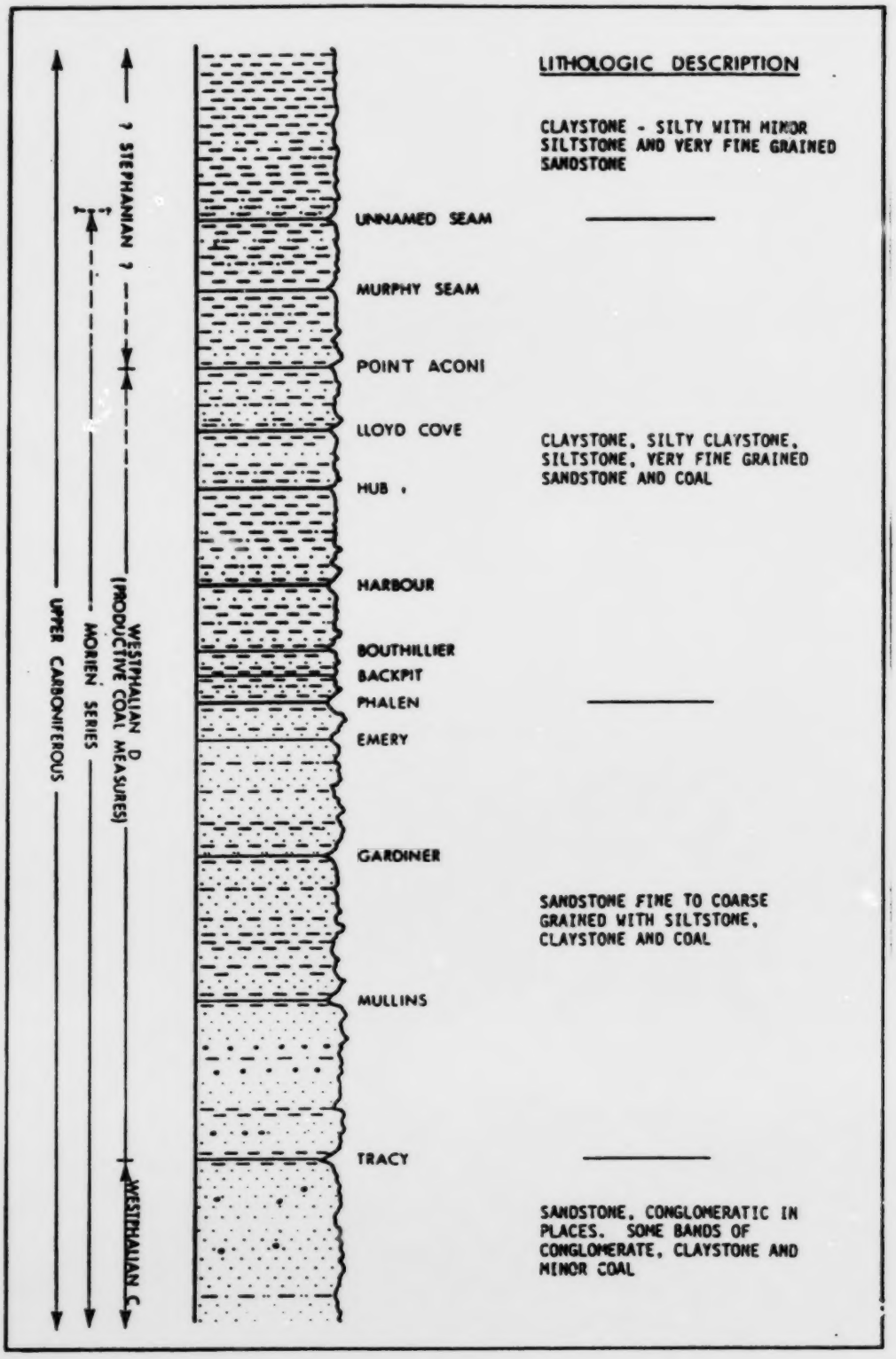


FIGURE 2-3

GENERALIZED STRATIGRPHIC COLUMN OF THE SYDNEY COALFIELD

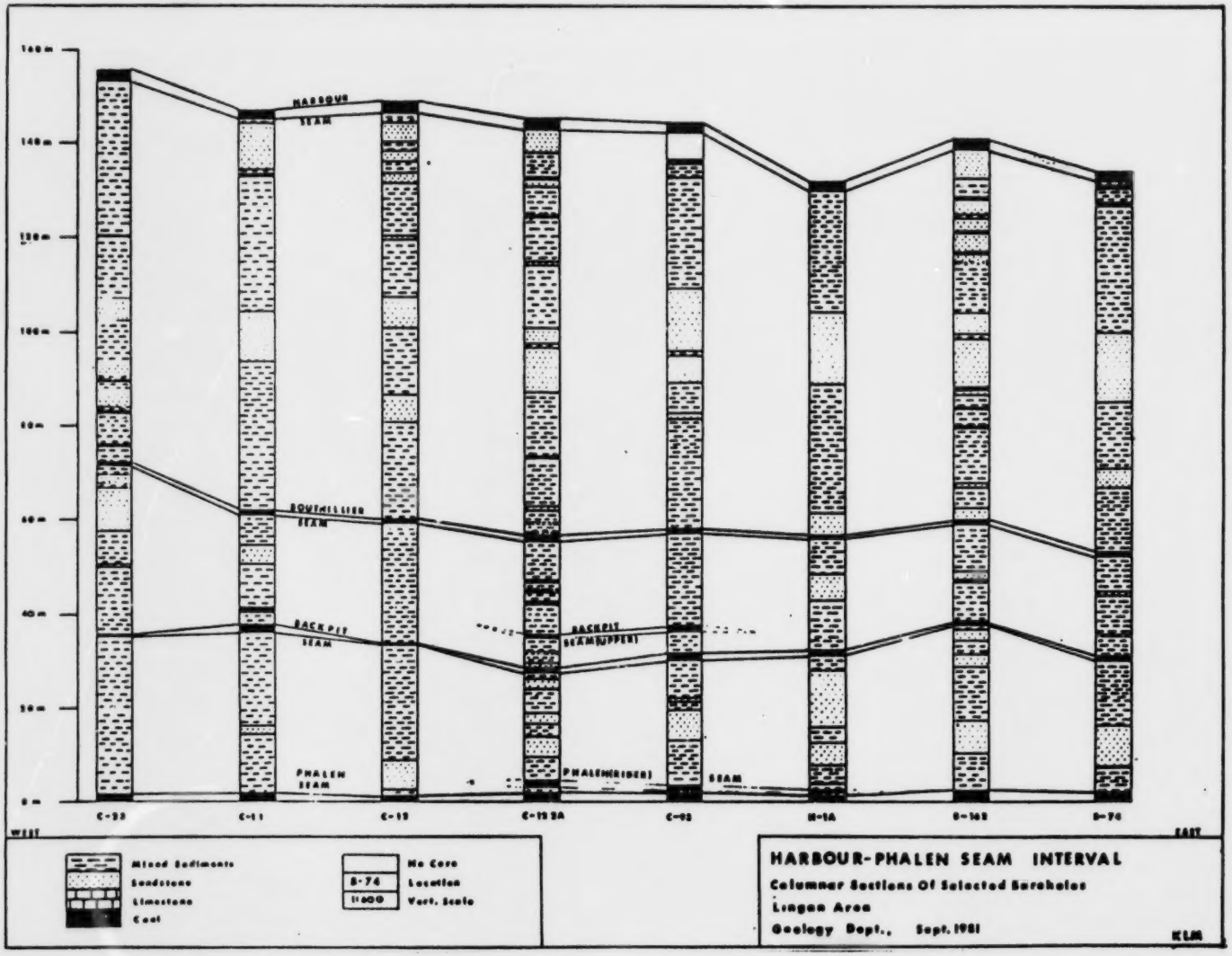


FIGURE 2-4

HARBOUR - PHALEN SEAM INTERVAL

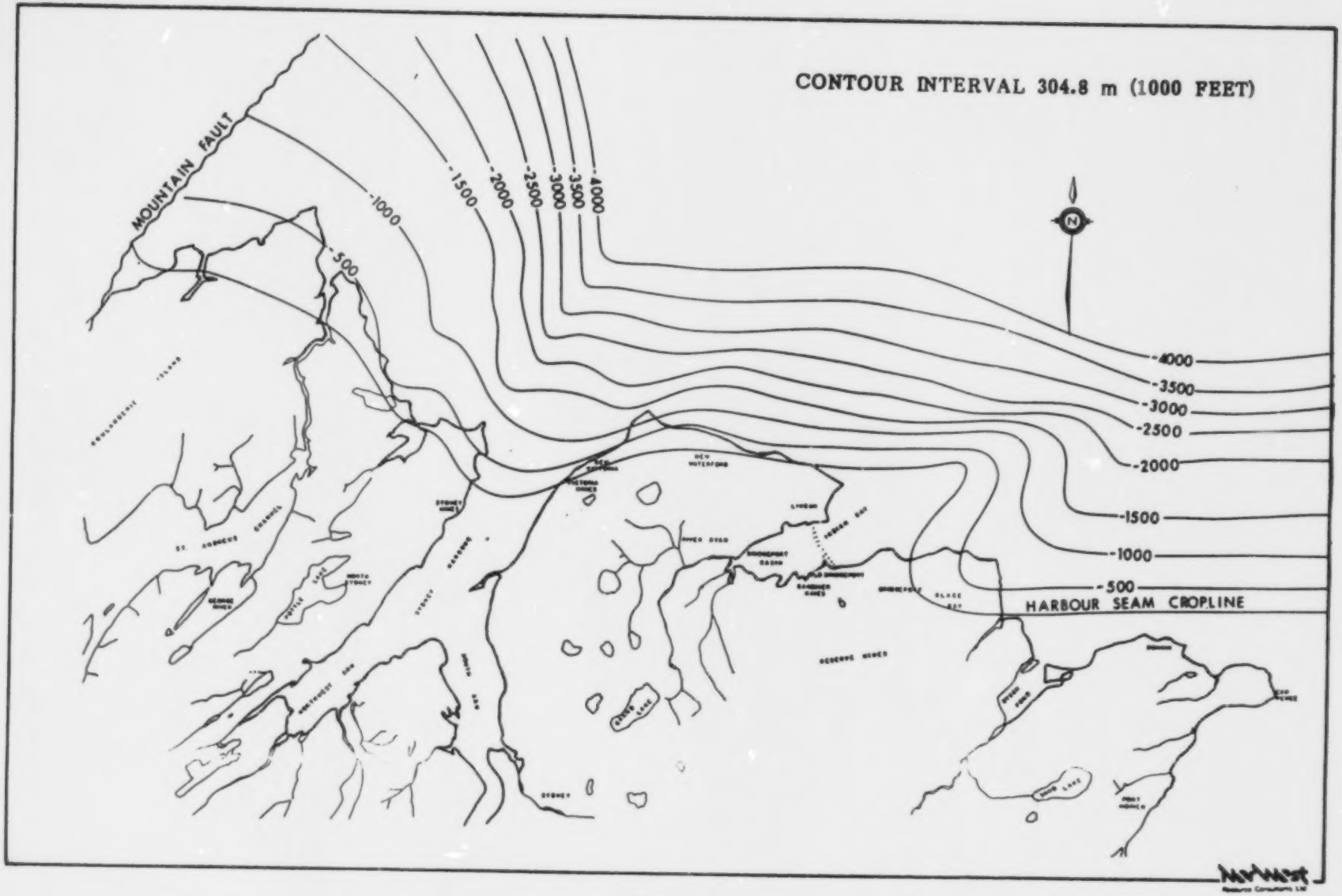
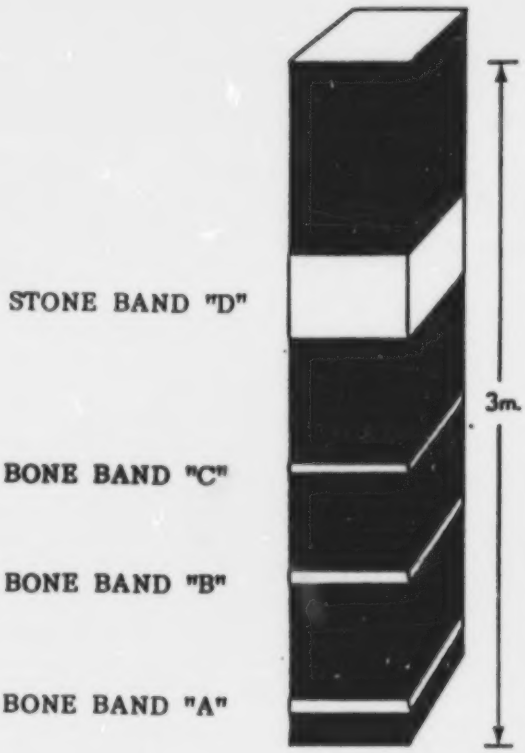
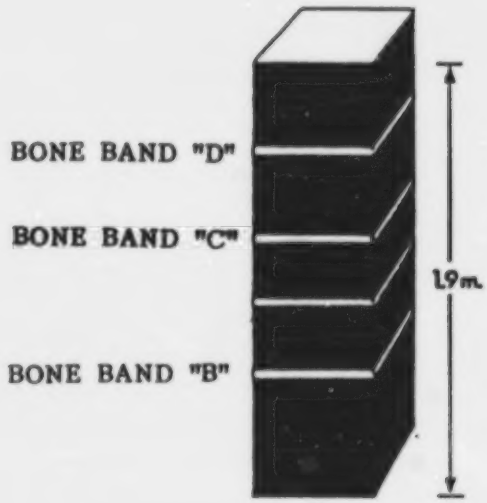


FIGURE 2-5

STRUCTURE CONTOURS, BASE OF HARBOUR SEAM



PHALEN SEAM IN THE VICINITY OF THE OLD LINGAN MINE NEAR THE WESTERN RESOURCE LIMIT



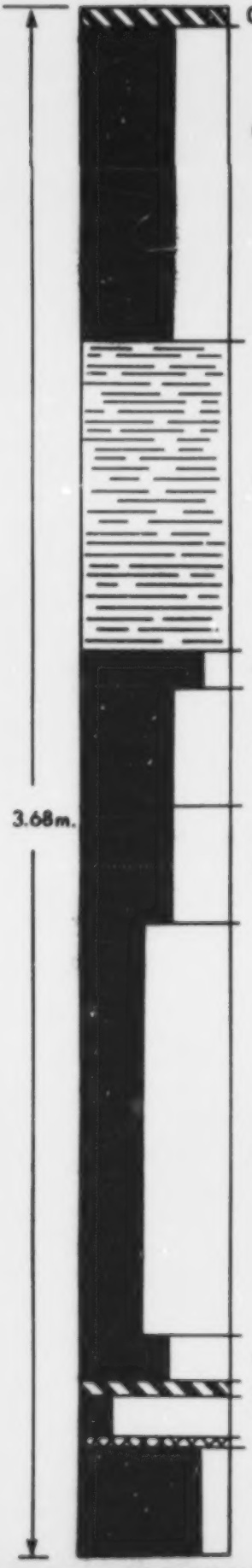
BAND "A" IS NOT PRESENT IN THIS PART OF THE COLLIERY

HARBOUR SEAM IN THE VICINITY OF THE CENTRE OF #26 COLLIERY

FIGURE 2-6

REPRESENTATIVE SEAM PROFILES OF THE HARBOUR AND PHALEN SEAMS

TYPICAL SECTION FOR THE PHALEN SEAM IN THE LINGAN PHALEN AREA



0.05m. Intermediate to bright banded coal; locally, contains dull bands of durain; well developed cleat; coated with scales of transparent carbonate; fusain lenses (up to 0.02' thick) common throughout section.

0.79m.

0.79m.

0.10m. Intermediate to bright banded coal; minor ankerite along cleat; contains a few streaks of pyrite.

0.15m. Intermediate to bright banded coal; highly broken in core box; high in fusain.

3.68m.

0.15m. Intermediate to bright banded coal; minor ankerite along cleat; slickensided joint dipping at an angle of 70° observed; 1/8" thick durain band in top 1"; 1" durain band in lower 1".

1.08m. Bright banded coal; thin fusain lenses present throughout section; carbonate along cleat, locally contains pyrite.

0.12m. Intermediate to bright banded coal, quite high in fusain, streaks of pyrite along cleat, ankerite along cleat.

0.04m.

0.11m. Splint, hard, high in ash and pyrite.

0.03m.

0.28m. Intermediate to bright banded coal, pyrite common along bedding; some fusain containing pyrite, top 2" mostly dull.

FIGURE 2-7

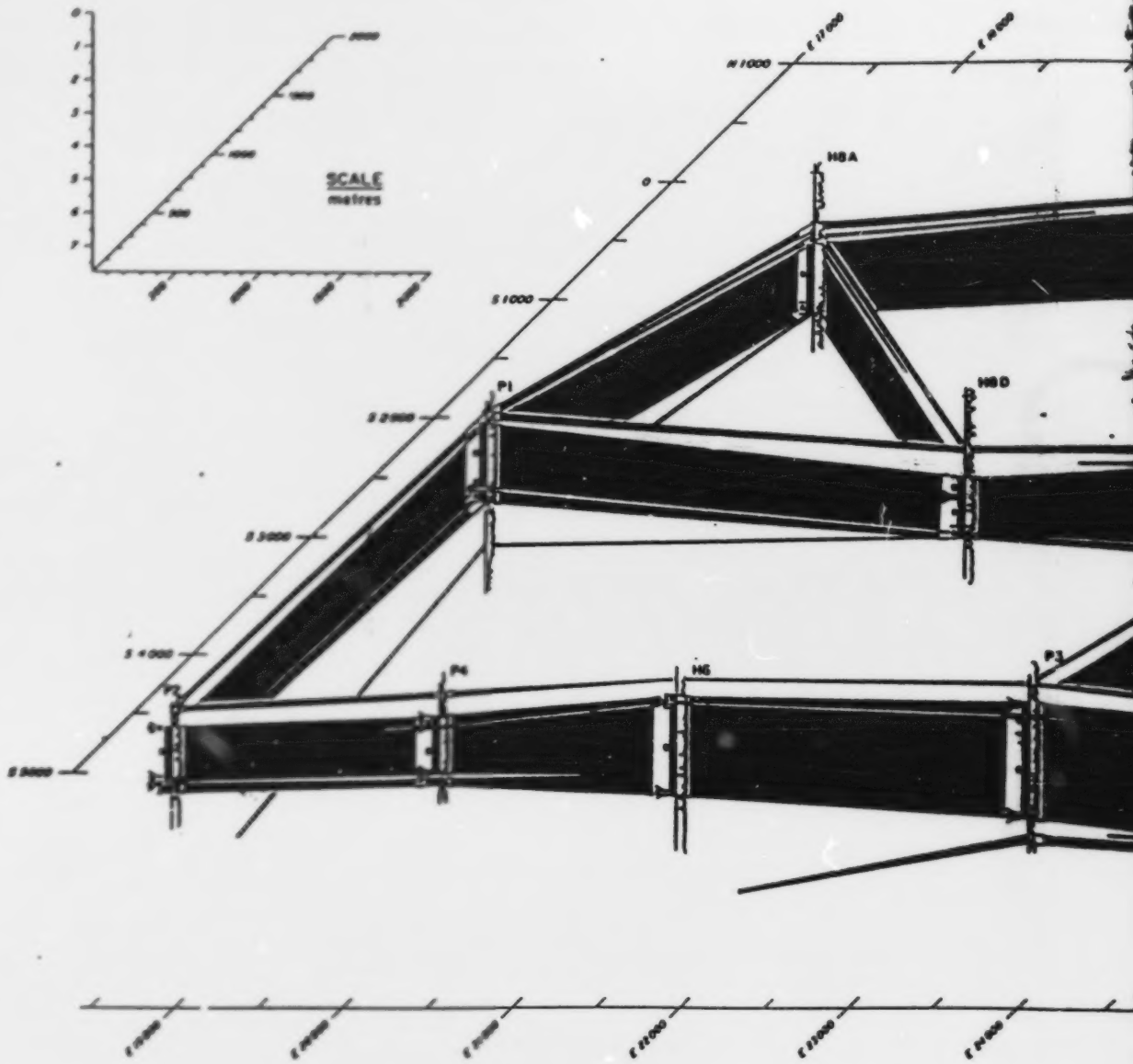


FIGURE 2-
FENCE DIAGRAM, HA

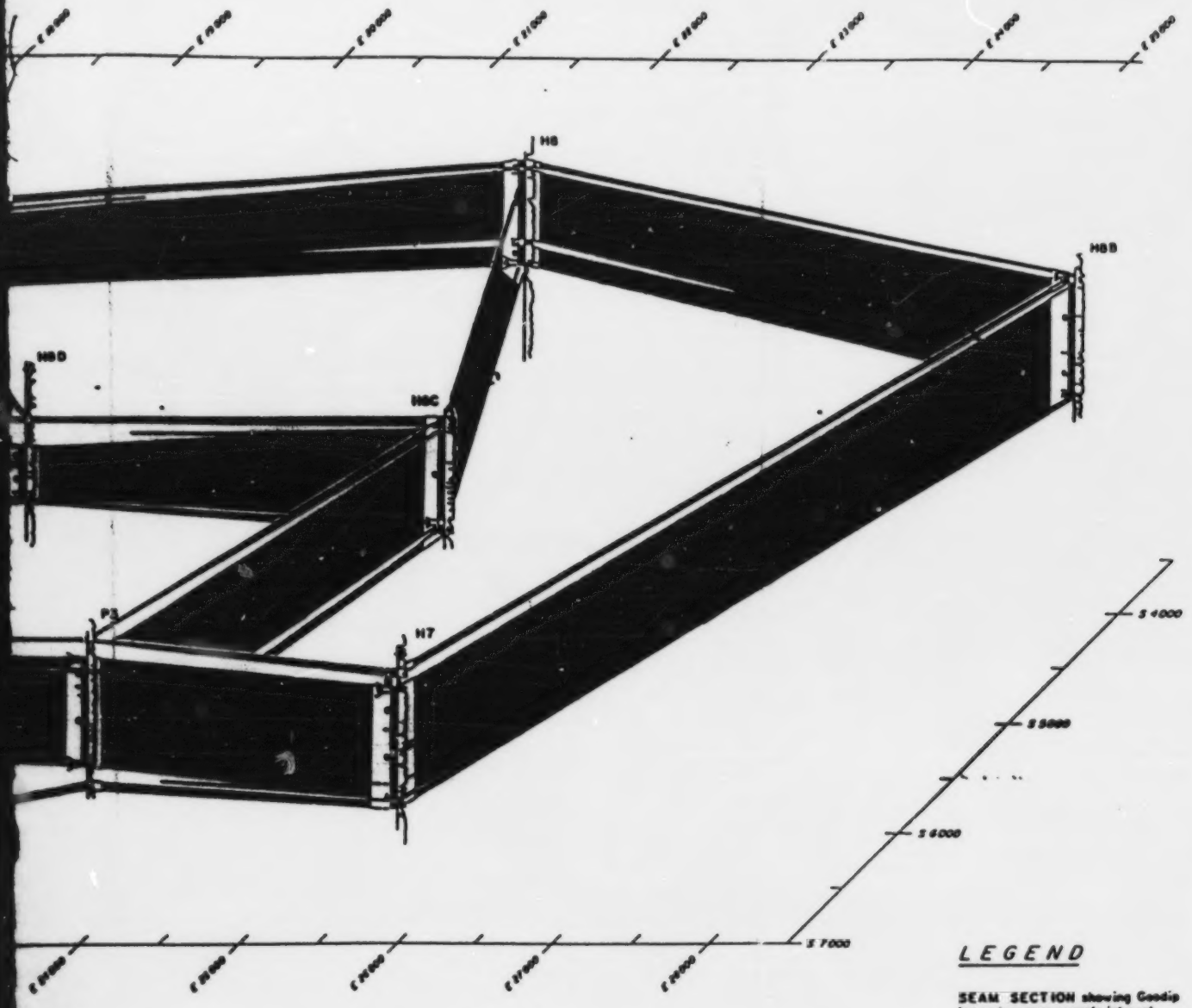


FIGURE 2-8

AGRAM, HARBOUR SEAM

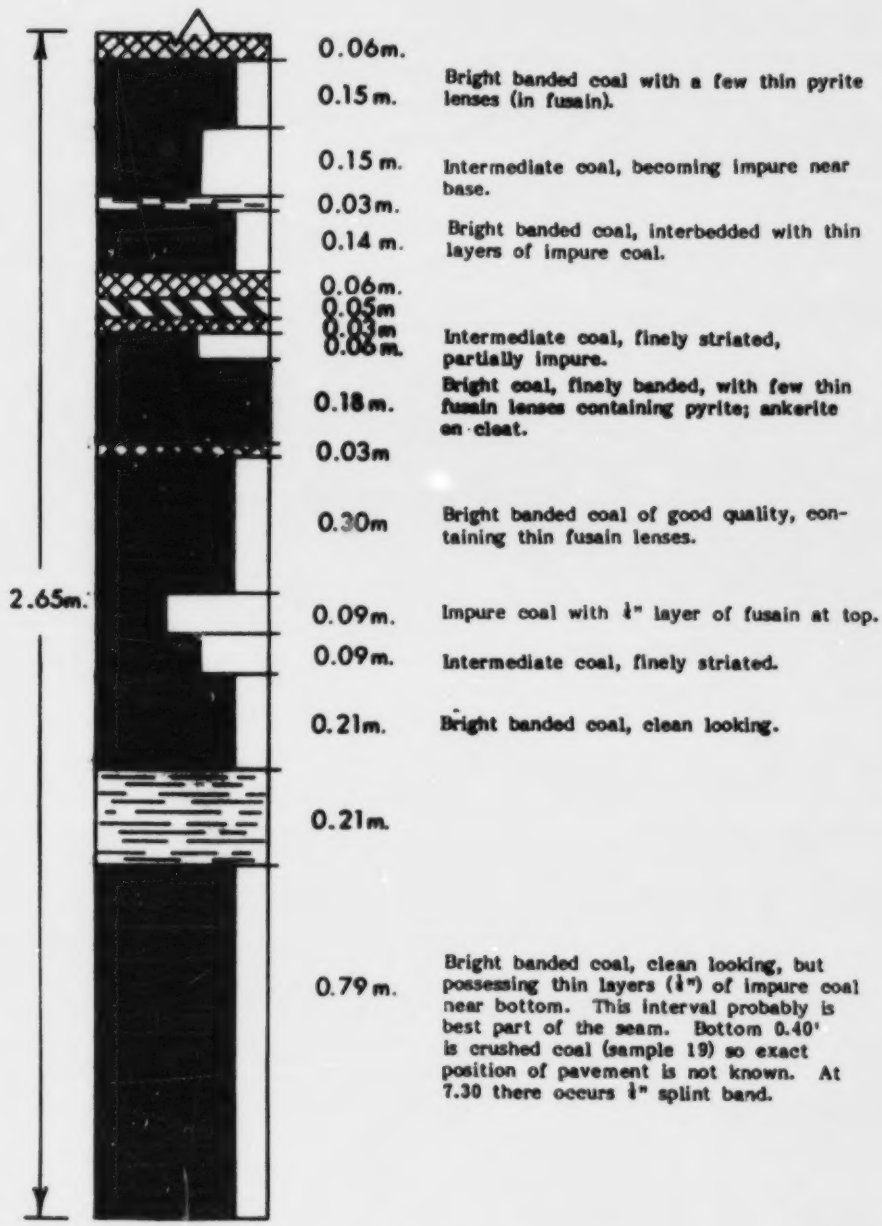

2.65m.
0.06m.
0.15m.
Bright banded coal with a few thin pyrite lenses (in fusain).
0.15m.
Intermediate coal, becoming impure near base.
0.03m.
0.14 m.
Bright banded coal, interbedded with thin layers of impure coal.
0.06m.
0.05m
0.03m
0.06m.
Intermediate coal, finely striated, partially impure.
Bright coal, finely banded, with few thin fusain lenses containing pyrite; ankerite on cleat.
0.18m.
0.03m
0.30m
Bright banded coal of good quality, containing thin fusain lenses.
0.09m.
Impure coal with ¼" layer of fusain at top.
0.09m.
Intermediate coal, finely striated.
0.21m.
Bright banded coal, clean looking.
0.21m.
0.79m.
Bright banded coal, clean looking, but possessing thin layers (¼") of impure coal near bottom. This interval probably is best part of the seam. Bottom 0.40' is crushed coal (sample 19) so exact position of pavement is not known. At 7.30 there occurs ¼" splint band.

FIGURE 2-9

TYPICAL SECTION FOR THE HUB SEAM IN THE PRINCE MINE

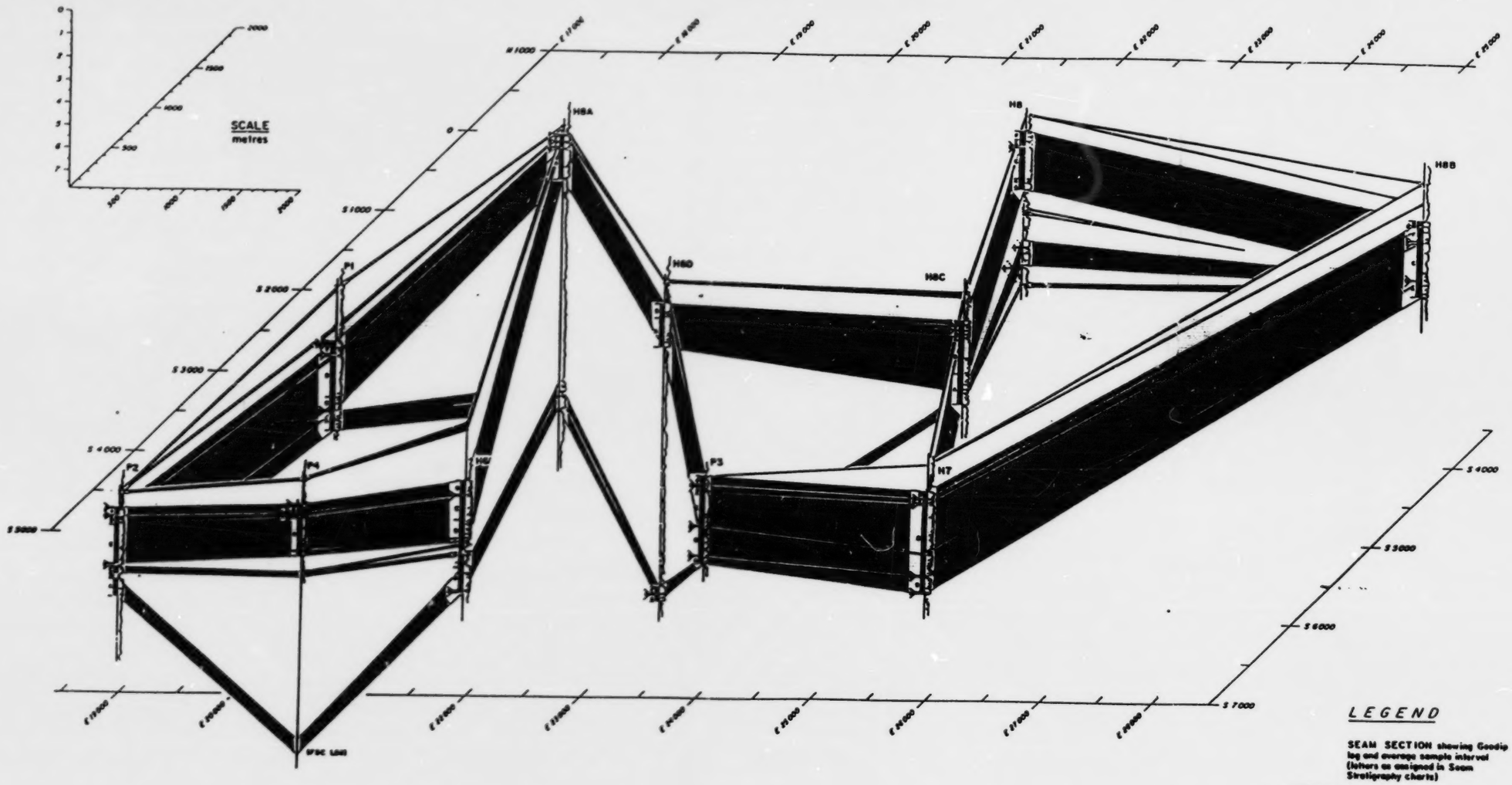


FIGURE 2-10
FENCE DIAGRAM, HUB ZONE

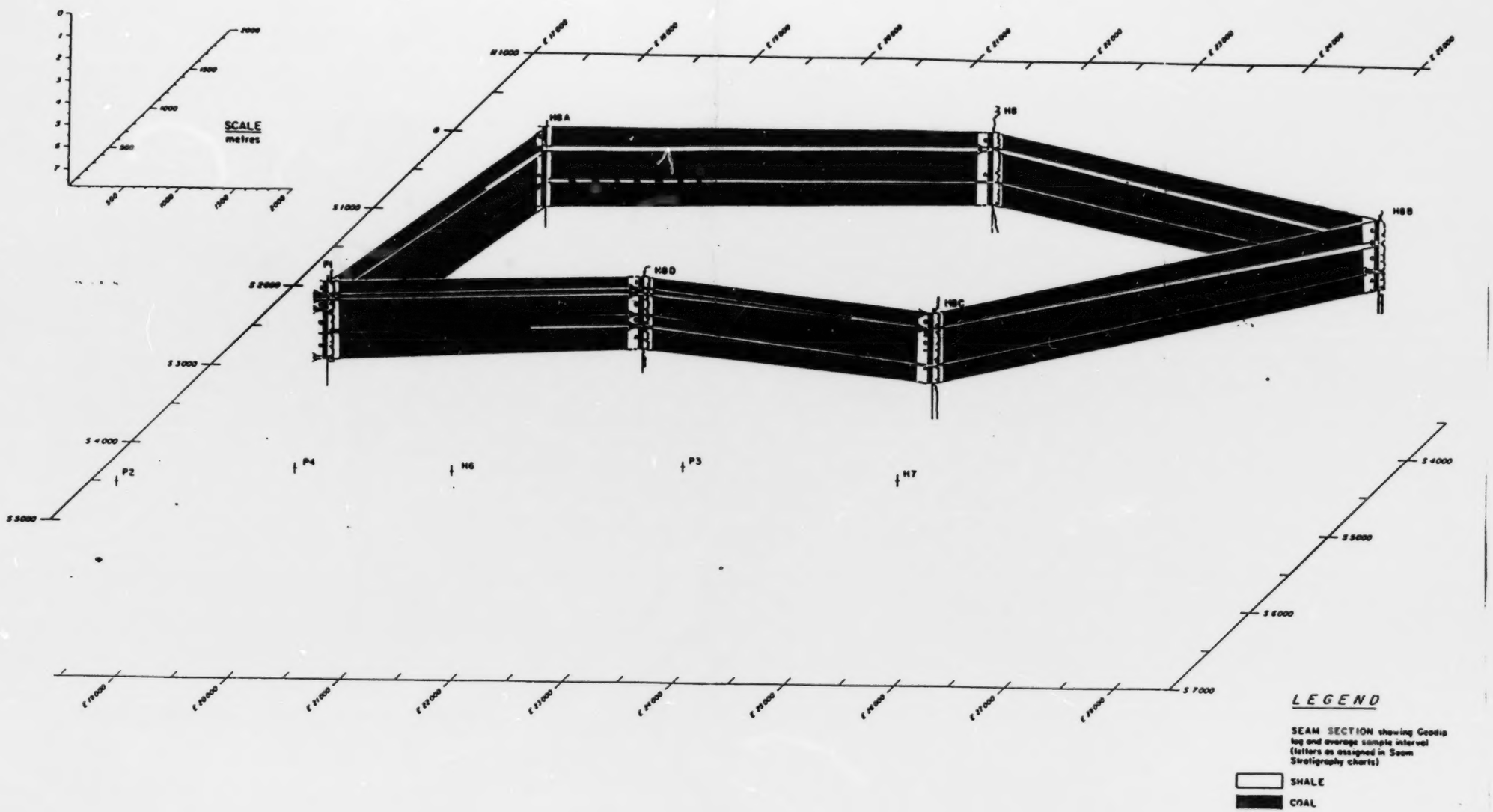
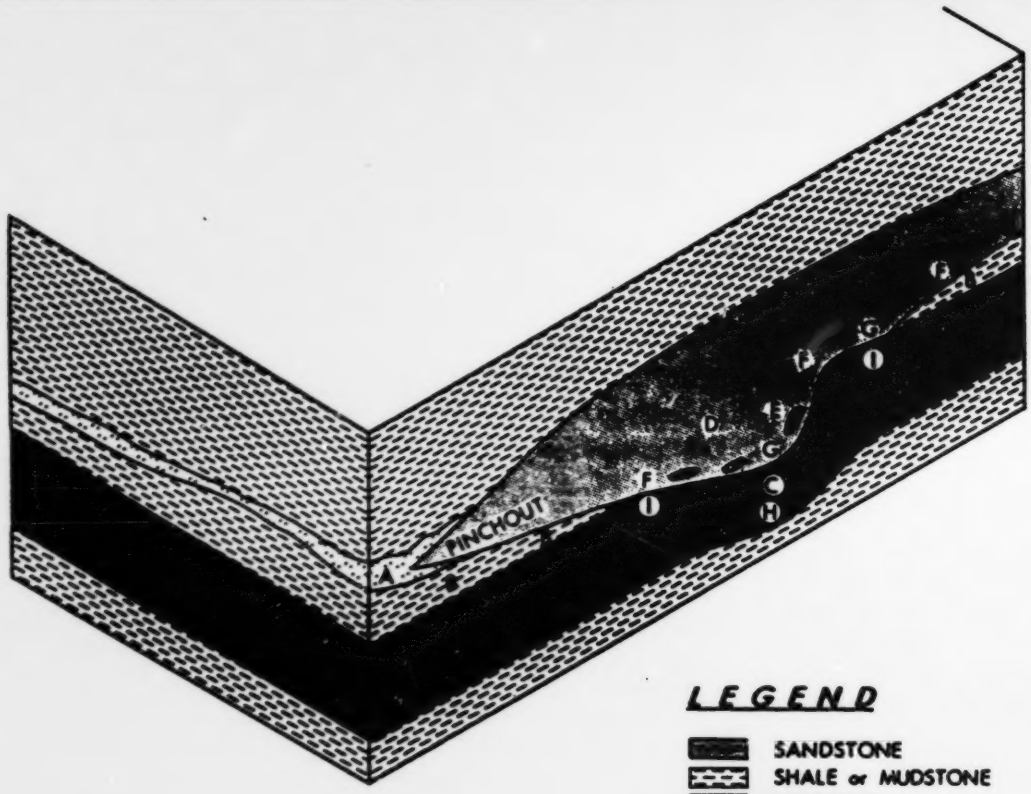


FIGURE 2-11
FENCE DIAGRAM, LLOYD CAVE SEAM



LEGEND

- SANDSTONE
- SHALE or MUDSTONE
- SILTSTONE
- COAL
- PYRITE

(A) ROCK INTO WHICH SANDSTONE PINCHES OUT (BECAUSE OF DISRUPTION DUE TO DIFFERENTIAL COMPACTION) IS WEAK. ROCK TENDS TO FALL. FALLS IN EXCESS OF 5 FT. HIGH ARE COMMON.

(B) BECAUSE OF THE LOW ADHERENCE STRENGTH ALONG THE CONTACT BETWEEN SANDSTONE AND SHALE OR MUDSTONE, ROOF ROCK ABOVE THE SEAM TENDS TO SPALL OFF INTO WORKINGS. FALLS GENERALLY RANGE FROM A FEW INCHES TO SEVERAL FEET ABOVE THE SEAM.

(C) BECAUSE OF THE EROSIVE ACTION OF STREAM CHANNELS THE MINABLE COAL HEIGHT CAN BE REDUCED.

(D) THE SILICIOUS NATURE OF SANDSTONE CONSTITUTES A SAFETY HAZARD DUE TO "SPARKING" WHEN STRUCK BY THE PICKS OF A SHEARING DRUM.

(E) PYRITE IS COMMON ALONG THE SANDSTONE-COAL CONTACT. THIS MINERAL ADDS TO THE INCENDIVE NATURE OF THE SANDSTONE

(F) WATER IS COMMONLY FOUND ALONG THE COAL-SANDSTONE CONTACT. INFLUX INTO THE WORKING (USUALLY MINOR) LEADS TO SLIPPERY AND GENERALLY UNCOMFORTABLE WORKING CONDITIONS.

(G) METHANE GAS INFLOW CAN BE FOUND TO OCCUR ALONG THE STANDSTONE-COAL CONTACT.

(H) MOST SANDSTONE INTRUSIONS HAVE AN ASSOCIATED "LAG" OR STRUCTURAL SYNCLINE. CUTTING BY THE SHEARER CAN BE DIFFICULT IN THIS ZONE.

(I) THE SULPHUR CONTENT OF THE COAL TENDS TO BE HIGHER IN THE AREAS WHERE SANDSTONE LIES ON TOP OF THE COAL

PROBLEMS ASSOCIATED WITH
STONE INTRUSION

REPRODUCED FROM S. FORGERON, 1980.

FIGURE 2-12

PROBLEMS ASSOCIATED WITH STONE INTRUSION

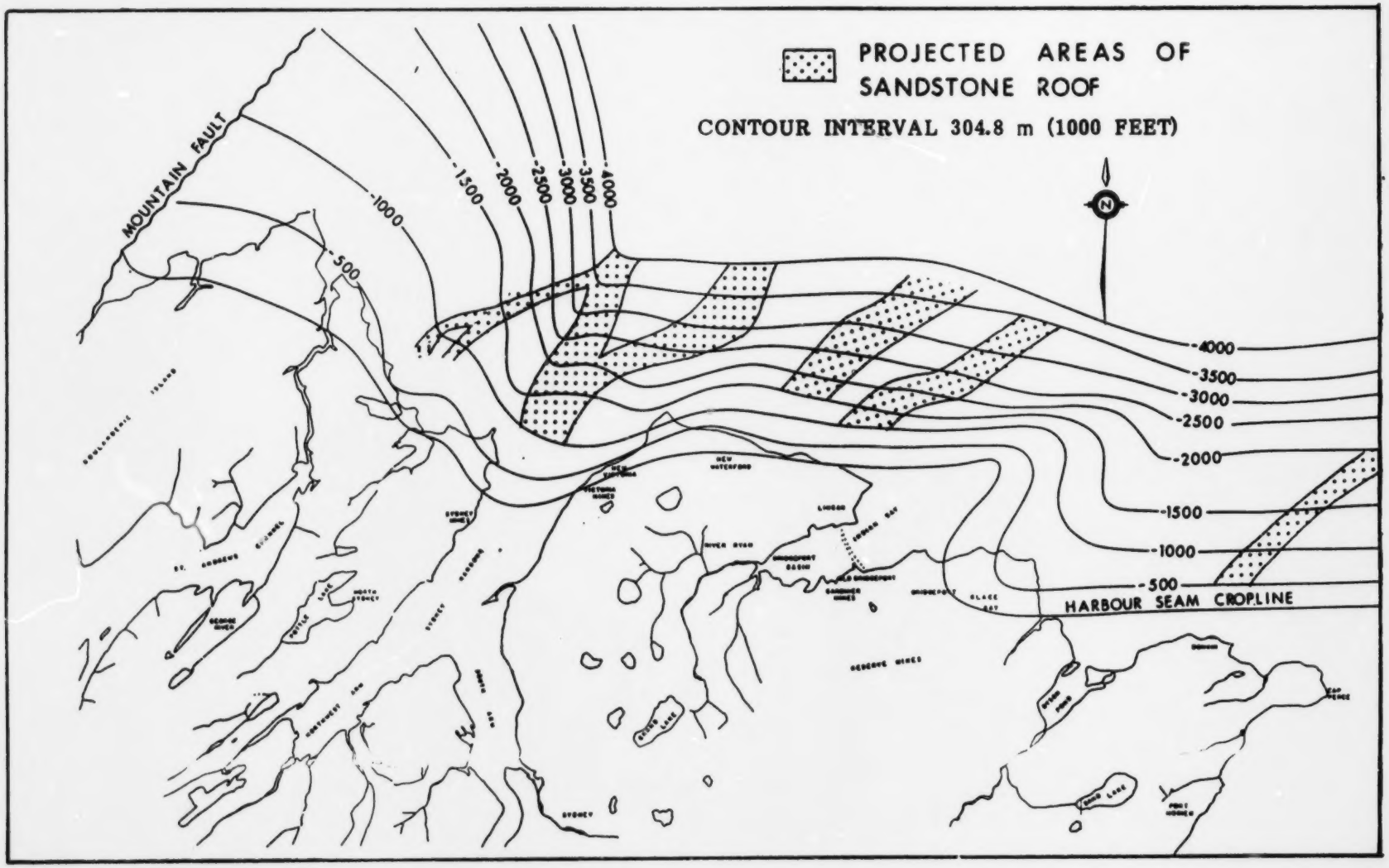


FIGURE 2-13

HARBOUR SEAM STRUCTURE

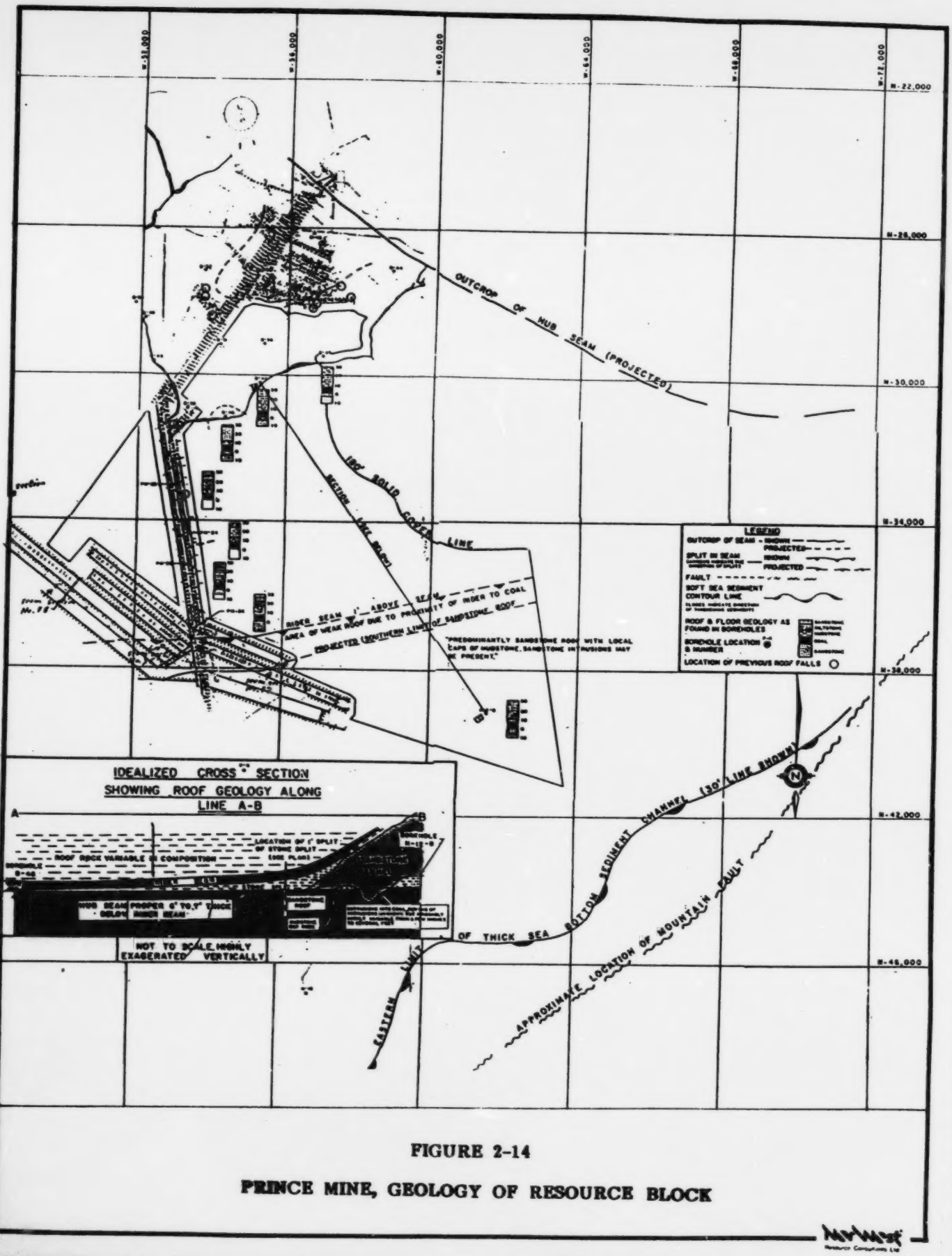
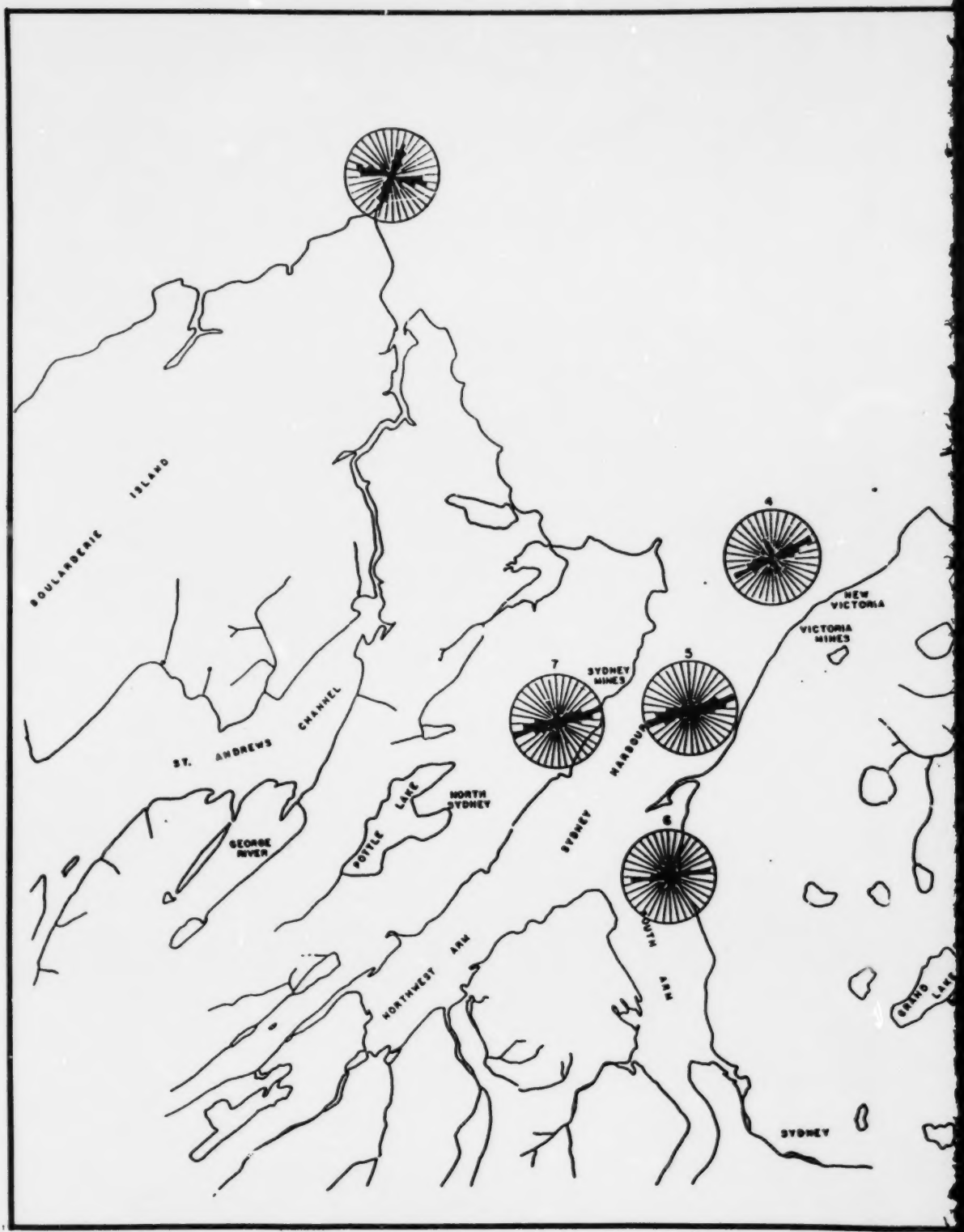


FIGURE 2-14

PRINCE MINE, GEOLOGY OF RESOURCE BLOCK



FIGU

SYDNEY COALFIELD,

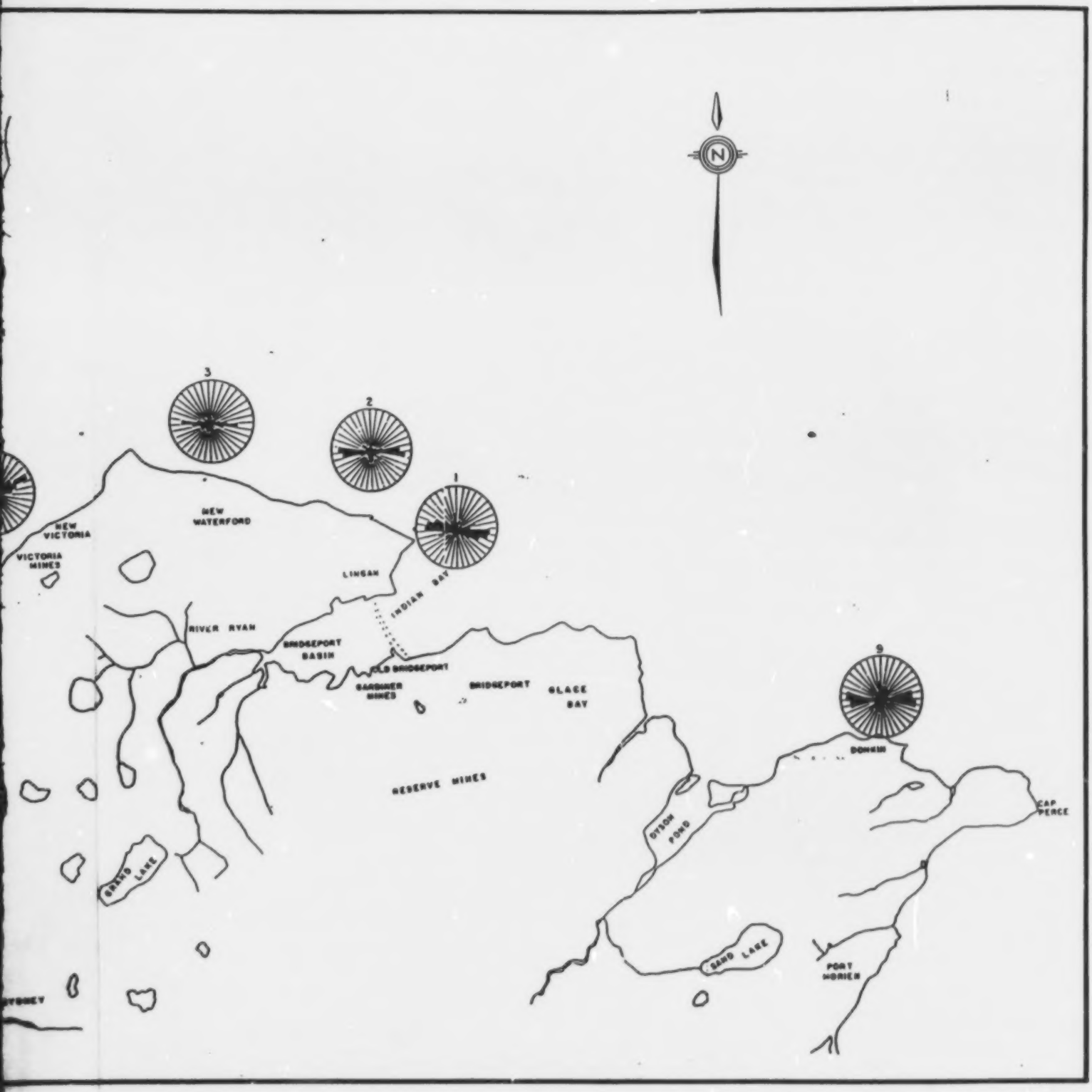


FIGURE 2-15

COALFIELD, JOINT ORIENTATION SURVEY

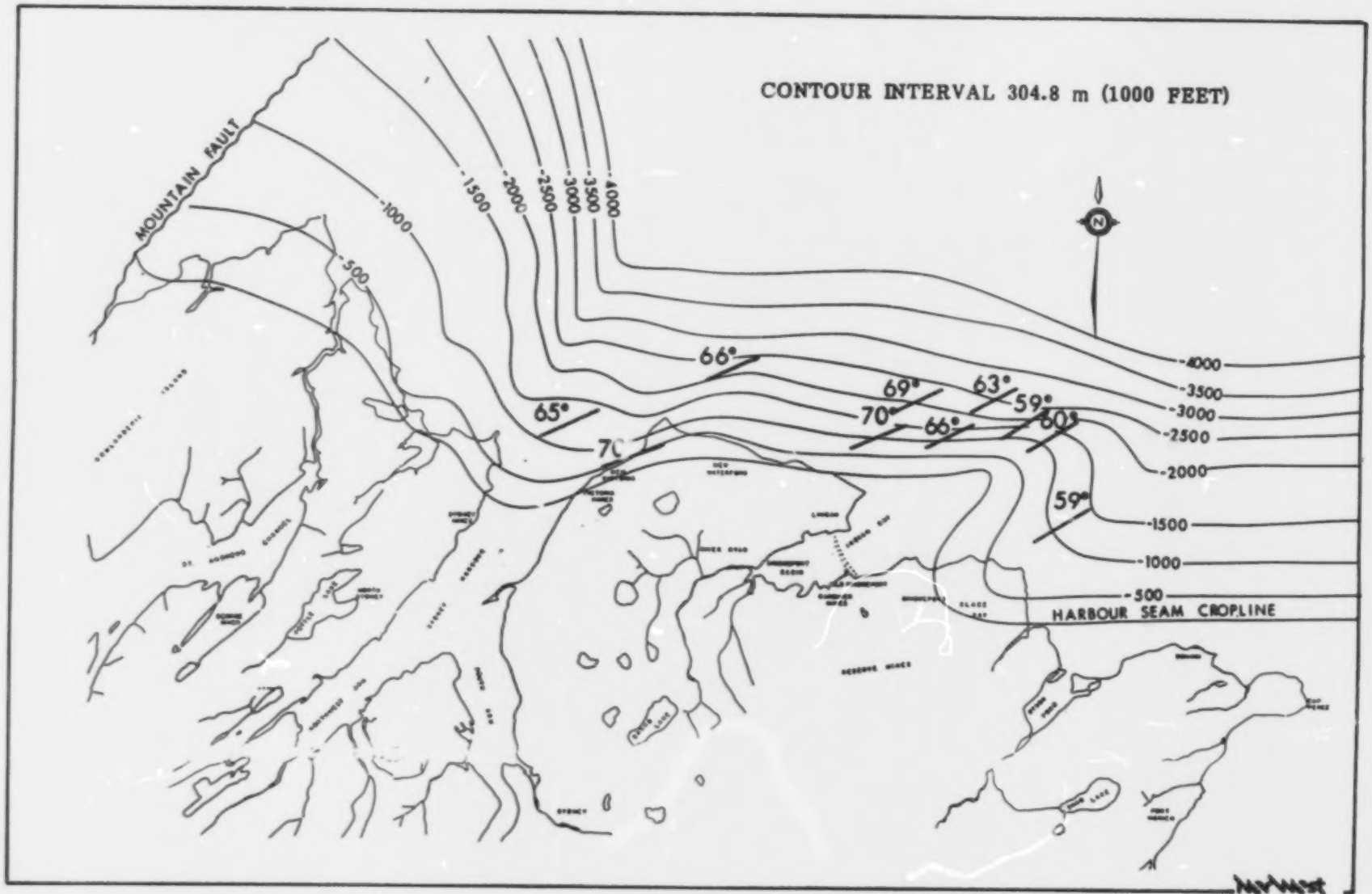


FIGURE 2-16
STRUCTURE CONTOURS AND CLEAT MEASUREMENTS
HARBOUR SEAM

SECTION 3

MINING OPERATIONS IN THE SYDNEY COALFIELD

3.1 GENERAL

Successful water infusion in high productivity mines must be efficiently integrated into the mining system. Usually a proposed water infusion installation will be designed to accommodate the constraints imposed by existing mining systems thus requiring little if any modification to mining plans or organization.

This section describes the mining operations presently producing from and planned for the Sydney Coalfield.

3.2 ACTIVE AND PROPOSED MINES

The principal mining activities on the Sydney Coalfield are conducted by the Cape Breton Development Corporation which operates underground mines in the Sydney/Glace Bay area. Figure 3.1 shows the location of the operating and proposed mines.

CBDC has two producing underground mines:

Prince Mine

This is an under-sea drift mine accessed by slopes, working the Hub Seam by short longwall retreat faces. Annual production is approximately 0.7 Mt saleable. The faces are equipped with double ended shearers, armoured flexible conveyors and power supports.

Lingan Mine

This is an under-sea drift mine, accessed by five slopes, working the Harbour Seam by longwall advancing faces. Annual production is approximately 1.2 Mt saleable. The faces are equipped with double ended shearers, armoured flexible conveyors and powered supports.

Major projects currently under construction or consideration by CBDC include three new mines: Lingan-Phalen, Glace Bay and Donkin-Morien.

Lingan-Phalen

This will be an under-sea drift mine to be accessed by four slopes to work the Phalen Seam by longwall retreat faces. Annual production is projected at 1.5 Mt. Faces will be equipped with double ended shearers, armoured flexible conveyors and powered supports. This mine is under development and is scheduled to commence production in 1986.

Glace Bay

This is a proposed under-sea planned to be accessed by two 1200 m deep shafts with horizons at 600 m and 1200 m. It will work the Harbour and Phalen Seams by longwall retreat faces. Annual production is projected at 2 to 3 Mt. Faces will be equipped with double ended shearers, armoured flexible conveyors and powered supports. No date has been set for production.

Donkin

This will be an under-sea drift mine to be accessed by four slopes and long horizon tunnels, to work the Harbour, Hub and Lloyd Cove Seams by longwall retreat faces. Annual production is projected at 4 Mt. Faces will be equipped with double ended shearers, armoured flexible conveyors and powered supports. The first tunnel should contact the Harbour Seam at a distance

about 3.5 km from the shoreline in December 1984. Coal quality tests and other appraisals will be made before a production decision is taken.

3.3 CURRENT MINING PRACTICE

3.3.1 Mine Geometry

Present mine layouts are based on a central system of dip (deep) developments from which longwall panels are worked with the roadways along the strike. Typically, the panels are at or near right angles to the main dips, although the Lingan-Phalen layout envisages a panel alignment at approximately 60° to the main dips. Panels generally have long runs frequently in excess of 1000 m and in some cases up to 3000 m.

The bulk of production from the Sydney Coalfield has been from advancing longwall workings. In the most recently worked mines, Lingan and #26, extraction has been exclusively by advancing, except for a single retreat panel attempted several years ago at #26 which was unsuccessful using the equipment and techniques then available. The first successful application of retreat mining was at Prince, where a retreat face was established in 1979. The next generation of mines - Donkin, Glace Bay and Lingan-Phalen - are all planned for retreat working.

3.3.2 Development

The intake and return roadways and face lines for advancing panels are developed by DOSCO roadheaders taking the coal seam and a roof brushing. Support is by steel arches for the gateroads. Face developments are driven square section and supported on girders and props.

For retreat working at Prince, panel developments are driven by DOSCO dintheaders with a square cross-section taking the seam and occasionally a small floor brushing. The support is by steel girders on props.

3.3.3 Extraction

In the Prince and Lingan workings extraction is to the seam floor, although some floor rock is mined where exceptionally soft conditions prevail. Generally the whole seam is extracted up to the parting between the coal and the roof stratum. Where adverse conditions are encountered, it is common to leave a thin layer of roof coal to assist in strata control. Extraction height is generally between 1.8 and 1.9 m.

The lengths of advancing faces at Lingan and #26 have been in the range of 150 m and 250 m with a trend towards longer faces. Considerations of seabed strains often require that sub-optimum face lengths be worked under shallow cover and at Prince this factor has dictated relatively short length faces, in the range of 50 m to 150 m.

The faces are aligned between approximately 49^{o} to 66^{o} to the main cleat direction. The relationship between the face alignment and main cleat is as follows:

Mine	Face Alignment to Main Cleat
Lingan	57^{o} and 66^{o}
Prince	49^{o} and 58^{o}
No. 26	50^{o} and 58^{o}

All present and proposed longwalls are provided with electricity at 550 and 1100 volts, compressed air at a pressure between 1000 kPa and 1500 kPa and a water supply.

The coal conveying system presently in use and planned for future faces includes armoured face conveyors with capacities rated in at 600 t/h feeding 1060 mm gate belts via armoured stage loaders.

Materials handling to production panels is by diesel locomotive and/or endless rope haulage.

No major ingress of water is experienced on existing faces, nor is it anticipated in the planned mines. Nuisance water is handled by local pump installations.

3.3.4 Face Equipment

All production faces employ conventional modern longwall systems. Output is presently obtained from double ended ranging drum shearers. The machines at Lingan are typically Anderson Strathclyde 270 HP AMBROAS mechanically hauled machines. Two speed gear boxes provide drum speeds of 36 rpm and 55 rpm. The drum width is 760 mm and drum diameter 1500 mm to 1600 mm. The machines are fitted with pick face flushing and H.S.V. systems.

The Prince machines are 300 HP Anderson Strathclyde FIDD machines operating on Dynatrack chainless haulage. A single drum speed of 51 rpm is provided and drums are 685 mm wide x 1500 m diameter.

All operating faces are currently equipped with Hemscheidt shields, either two-leg or four-leg. The Prince supports have a setting pressure of 24 MPa and a yield pressure of 33 MPa. The Lingan supports have a setting pressure of 26 MPa and a yeild pressure of 33 MPa. Closed height of the shields is 1300 mm.

Armoured face conveyors by Dowty Meco, Huwood and Halbach and Brown are currently employed. Chains are two-strand, typically twin outboard configurations.

Advancing longwalls in the Sydney Coalfield are worked without "stables" and both ends of the faces are cut-out by the extended arm shearers. Roadway formation is practiced in three configurations - conventional behind

the face, "half'head" and "in-line". The retreat designs do not have stables or brushing.

3.3.5 Longwall Performance

The production performance from longwall faces in the Sydney Coalfield is good by international standards. Where normal strata conditions prevail, face performances have been achieved that are of world record standard. Average face performances over long periods are typically in excess of 2000 t/day of clean coal.

Results from three faces at Lingan and three faces at Prince provide an indication of the performance that must be maintained or improved on when applying any viable water infusion technique (Table 3.1).

Face production at Lingan, for example, averaged over 800 t/machine shift and the Prince 3 West face has established an average performance of more than 1000 t/shift.

Actual face performance is significantly effected by factors including roof conditions, floor conditions or strata irregularities. For this reason it is not possible to draw up quantitative general performance standards for future longwall faces. For the purpose of evaluating any candidate water infusion system it must have the potential of allowing production of at least 1500 t to be achieved on individual shifts.

Productivity from Lingan faces ranges between 16 t and 20 t/manshift. This figure includes all personnel in the district. Face productivity at Prince, which does not include the manpower used for development work, ranges between 34 t and 64 t/manshift. It is estimated that face productivity at Lingan excluding outbye workers, is in the range of 35 t to 40 t/manshift. For a water infusion system to be viable in terms of productivity it is estimated that it must allow face OMS of the same order to be achieved.

3.3.6 Environment

All current and proposed mines in the Sydney Coalfield employ exhausting main ventilation. The total air quantity at Lingan Mine is 189 m^3/s and at Prince Mine is 73 m^3/s.

The quantity circulated in each production district varies according to face conditions. Typical quantities for current faces are as follows:

Mine	Face	District Quantity (m^3/s)
Lingan	8E	31
	9E	24
	5W	32
Prince	4E	27

In the advancing sections in the Lingan Mine as a result of leakage through the goaf a considerable reduction in air quantity occurs between the outbye end of the district and the face. Quantities at the return end of the face and total quantity in the district of some Lingan faces are as follows:

Mine and Face	District Quantity m^3/s	Face Quantity m^3/s
Lingan 8E	31	18
Lingan 5W	32	21

On retreat districts at Prince face and district quantities are essentially the same.

Methane drainage has been widely practiced on longwall panels in the Sydney Coalfeild and is in use on all faces at Lingan and planned for all future faces except those at Prince. Drainage is by the inclined borehole method with holes drilled from the return roadway into the roof over the longwall

gob. Typical methane drainage rates are typically 0.2 m/sec pure methane at about 75% purity and 50% capture. Gas is piped out of the district and diffused into the main air flow in the return deeps. A project is currently in hand to extract methane and pipe it to the surface as a useable product.

All shearers currently in use in the coalfield have internal water sprays on the drums supplemented by external spray clusters. The Lingan machines are equipped with hollow shaft ventilators that provide a flow of air through the drum shaft to ventilate the back of the cut. Considerable efforts have been made by CBDC to optimize the delivery of water to the cutting area to suppress dust and to provide maximum protection against frictional ignition.

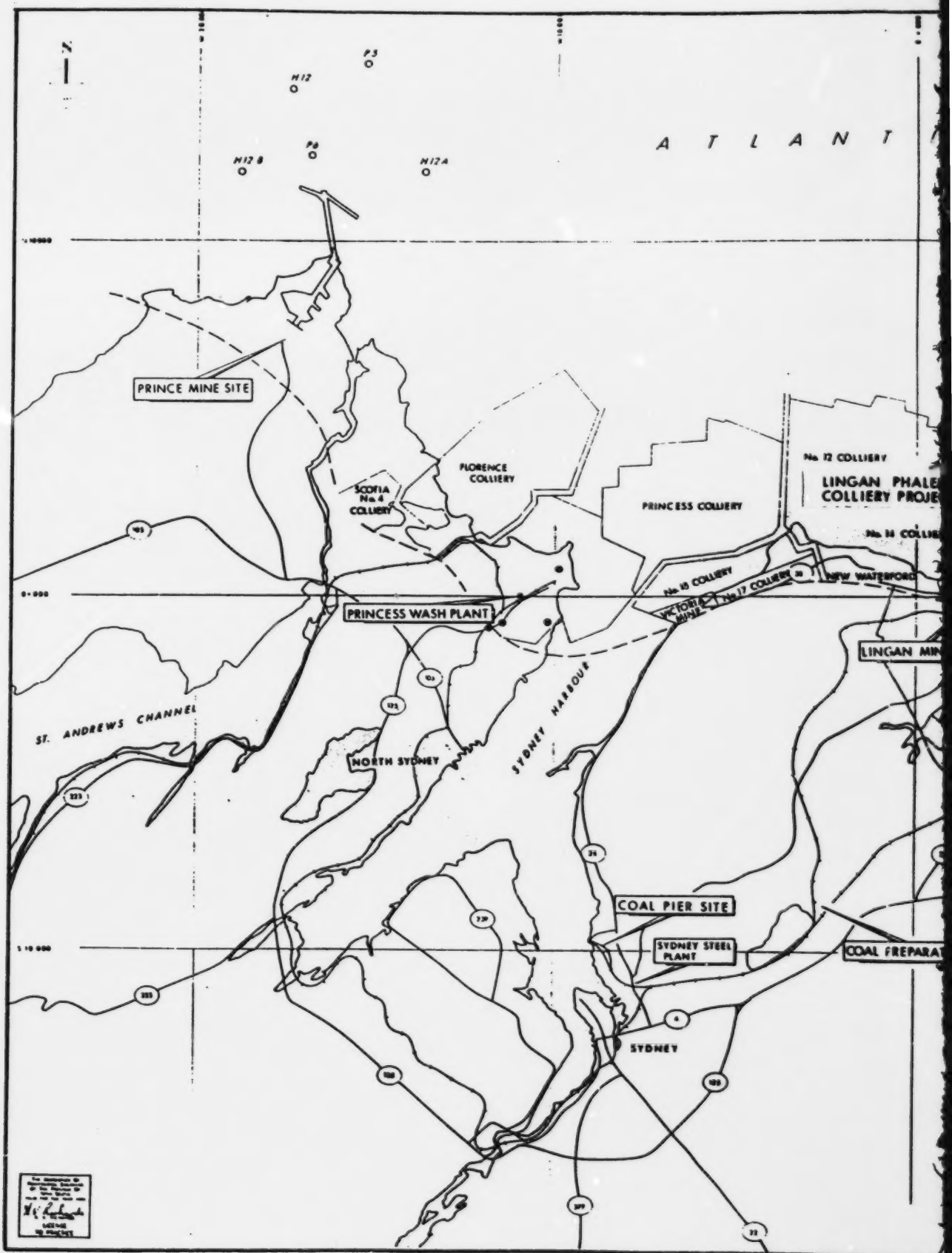
TABLE 3.1

WATER INFUSION TECHNOLOGY FOR DUST CONTROL
ON LONGWALL FACES

FACE PERFORMANCE
LINGAN AND PRINCE MINES

Face		Operational Period	Total Production (t)	Shift Production (t)	Face OMS (t/ms)
Lingan	7E	Oct 20/80 - Aug 25/83	1 158 372	750	19*
Lingan	3W	Jul 06/81 - Feb 10/84	686 831	514	16*
Lingan	4W	Nov 02/82 - Apr 19/84	677 980	812	20*
Prince	3E	Sep 12/82 - Oct 25/83	425 122	614	36
Prince	2W	Feb 02/82 - Sep 10/82	187 782	571	34
Prince	3W	Aug 19/83 - Feb 16/84	279 586	1092	64

* Includes district manpower



THE SYDNEY COALFIE

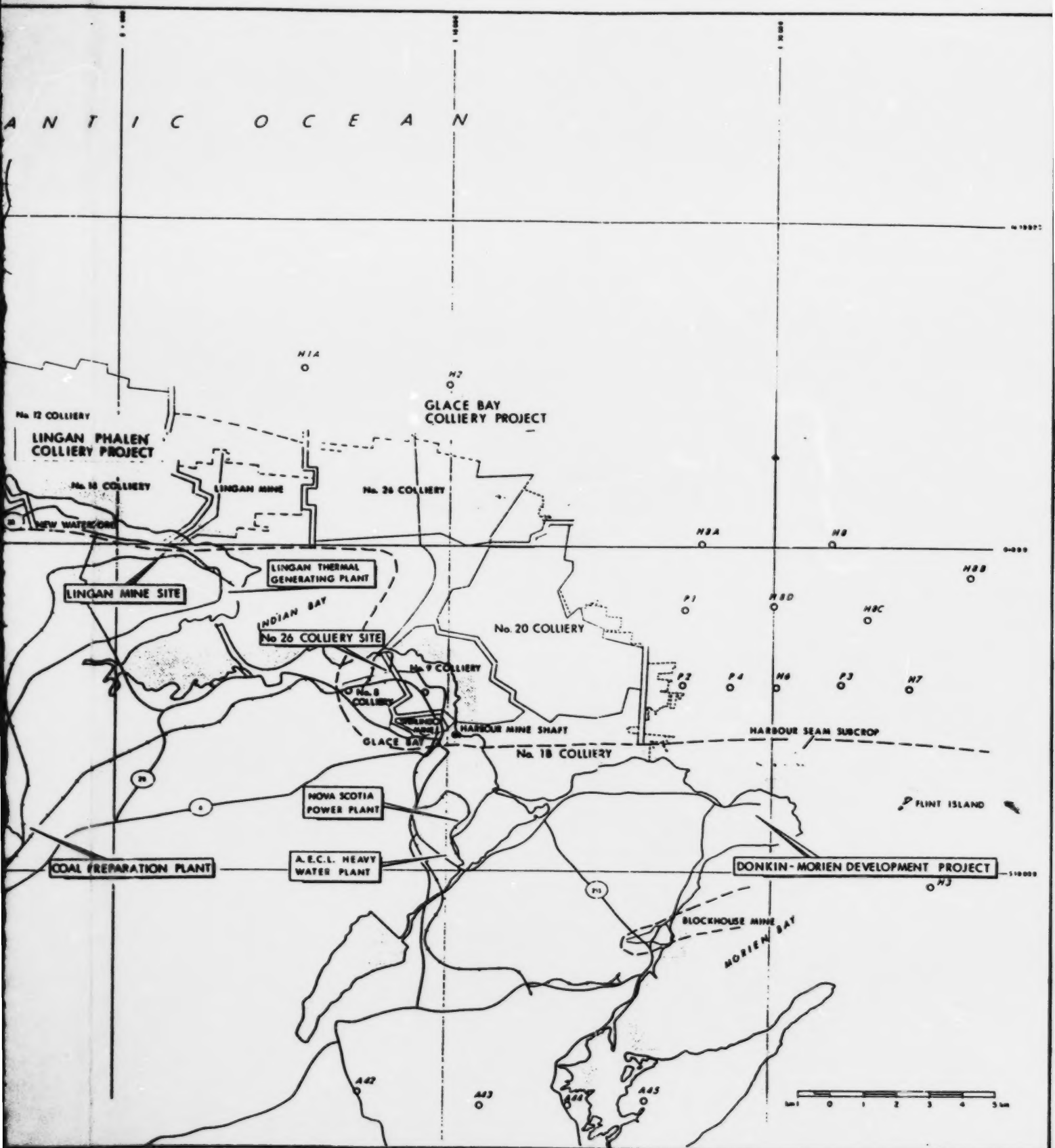


FIGURE 3-1

COALFIELD, GENERAL LOCATION MAP

SECTION 4

INFUSION CONSIDERATIONS

4.1 GENERAL

Water infusion has been used to control dust in many coal mines in Europe, the U.S.A., and Australia. The effectiveness of water infusion at a specific site has been shown to be constrained by the physical characteristics of the coal, the geological environment of the coal seam, the effects of methane gas and the accessibility of the coal seam. Consequently equipment and procedures for infusion have been designed to suit a wide variety of coals, environments and operating circumstances.

It has been shown that permeability is of paramount importance in determining the infusibility of a coal seam but that the ability of infusion to inhibit dust production at a mechanized face is not related simply to seam permeability. Dust production is effectively inhibited when the infusion water has permeated the mass of coal through sufficiently closely-spaced fractures to permit wetting of a significant number of surfaces along which the coal will break under the action of the cutting machine. This level of infusion corresponds with an increase in the moisture content of the coal of 1 to 3% above inherent moisture. Blocky coals which have high permeabilities along well-developed fractures which are widely spaced, may accept infusion water readily but effective dust inhibition may not result. In such circumstances the infusion water will travel rapidly through the coal and may emerge at the face or rib, migrate to structural lows in the coal seam or enter the roof or floor where damage to the adjacent beds may occur.

Mining in the Sydney Coalfield by retreat longwalls or advancing longwalls presents two distinct sets of operating circumstances in which to accommodate the water infusion procedure. Retreat mining at the Prince Mine will permit infusion through long holes drilled parallel to the face from

the head and tail roads well in advance of mining without interrupting the production cycle. Advance mining at the Lingan Colliery will permit the use of holes drilled from the face or gate ends, with consequent potential for interruption of production. Long hole infusion from the adjacent road may be feasible at the Lingan Colliery.

4.2 INFUSION TECHNIQUES

Water infusion techniques may be grouped according to the geometry of the installations, length of holes and water pressures employed. Mine and panel geometry constrain the selection of water infusion systems and it is therefore useful to categorize infusion techniques by their geometry.

There are three basic geometries which are referred to as:

- Infusion from the face
- Infusion from the roads
- Remote infusion

These are shown diagramatically in Figure 4-1.

Infusion from the Face

This is the oldest of the methods and has been extensively used in the UK, in the Federal Republic of Germany and in France. In the simplest example holes are drilled straight ahead from the face to a depth approximately 0.5 m greater than the daily advance. Water is infused through the holes for either the time available between cutting shifts or some time determined by experience to be appropriate. The pressure under which the infusion water is introduced varies substantially between operations but the limited time available for infusion generally requires high infusion pressures to provide the necessary quantity of water.

Infusion from the face has been used with longer holes, approximately 5 times the daily advace. In some instances staggering of long and short holes or a pattern of long holes which is extended stepwise Figure 4-2 was implemented to reduce the impact of infusion operations on face productivity and to reduce the probability of water short-circuiting back to the face. Stress conditions ahead of the face have been reported to interfere with deeper hole infusion particularly with regard to insertion and removal of the infusion probe (Becker, 1972).

Infusion from the Roads

Holes for infusion can be drilled parallel to the face in retreat longwall panels and in some advancing panels where headings are maintained ahead of the face.

This technique requires the use of long hole drilling equipment to prepare accurately aligned holes parallel to the bedding. Holes may be drilled from one or both sides of the panel. Utilization of holes from the head and tail entries permits even infusion over the face from shorter holes than are usually necessary if all drilling is conducted from one side.

In retreat mining, infusion from the roads can commence at any position in front of the face and it has been shown (Ducrocq, 1972) that long term, low pressure infusion, sometimes called continuous infusion, is effective in introducing sufficient water into the coal to suppress dust at the face. The time available for infusion through long holes drilled from advance headings on advancing longwalls is more limited and higher pressure may be required to infuse the desired amount of water.

Recent practice in infusion from the roads has been to use cement grout to seal the infusion probe into the holes. This method of sealing has been adopted in all cases reported in the literature in the last decade.

Holes may be up to 100 m in length with a grouted length of up to 60 m. Spacing is a function of the local conditions and varies with the patterns of holes used. Figure 4-3 shows examples of how the infusion water distributies with different patterns. Infusion water pressures vary with local conditions, high pressures have been reported as being occasionally necessary to condition new infusion holes for short periods of time prior to reducing the pressure for sustained infusion. It is usual to continue low pressure infusion until the hole is cut by the face or until significant leakage through the face occurs.

Remote Infusion

This technique finds application in European coalfields where several seams are mined or in steeply dipping seams where infusion holes are drilled from workings remote from the seam to be infused. As in the case of infusion from the roads, long holes are necessary and cemented grouts are commonly used for sealing the probes into holes. The length of the hole which intersects the seam is a function of seam and hole orientation but the ungrouted portion of the hole (infusion chamber) is normally shorter than in holes drilled parallel to the bedding as in infusion from the roads.

Variations on these techniques have been reported for very thick seams (Ganier, 1972), high speed advance workings (Becker, 1972) and in mines using specific mining equipment. Discussion of the infusion systems most applicable to the Sydney Coalfield is presented in section 4.4 and 4.5.

4.3 EFFECTS OF WATER INFUSION

Installation of a water infusion system would be contemplated where a beneficial effect was intended. The usual intention is to supress dust in the workings but experiments have been reported where infusion was used to inhibit the inflow of methane (Cervik, 1977). It has also been reported that infusion of water may assist in reducing the power required to cut coal

at the face or induce faster cutting speeds. Potential undesireable effects of water infusion are water damage to the roof or floor of the seam and flooding of depressions in the floor where water accumulation can create a nuisance rather than a hazard.

The significant desireable effects of infusion are the control of airborne dust and methane; these are discussed with reference to existing operations in the Sydney coalfield.

Airborne Dust

Conventional dust suppression techniques are employed at the mines in the Sydney Coalfield. The dust levels in the mines are presently controlled to within established standards (8 mg/m^3 respirable dust) but additional measures may be required to comply with more rigorous future standards or to accommodate increased productivity.

Implementation of successful water infusion will not eliminate the need for conventional dust suppression at the face and in the coal handling system but may effectively lower the levels of respirable dust when implemented as a complementary suppression technique.

A combination of water infusion with properly applied water sprays at the face and critical locations in the coal handling system may be expected to deliver a substantially lower airborne dust concentration in both respirable and larger dust sizes. Reducing the concentration of respirable dust has obvious health benefits and will enable compliance with future standards without recourse to higher volumes of ventilation air. Improvement in the levels of total dust in the working places may have an effect on productivity and safety by improving visibility and the comfort level of the miners.

Water infusion has been reported as reducing the respirable dust at critical locations by amounts ranging from 20% to 80% in mines in the U.S.A. and Europe.

Methane

The seams of the Sydney Coalfield are considered as moderately to highly gassy. Methane drainage is employed and methane collection has recently been implemented at Lingan Colliery where 2.5 million cubic metres of 60% purity methane will be extracted daily.

The USBM has reported several studies designed to evaluate the impact of water infusion on methane production from coal seams. These studies indicate that:

- gas pressure in the seam has to be overcome by infusion water,
- when the fissure system in a coal seam has been effectively infused, methane does not migrate through the infused zone (water barrier),
- concentration of methane at the face increased as infusion progressed but decreased below normal levels when a water barrier was effected,
- methane migration was diverted by water barriers and the gas tended to enter the workings by alternative routes being detected in greater than normal quantities in the gate roads or entries.

Methane production from a mine district will not be affected by water infusion but some change in the distribution of methane flow patterns within districts may be expected as a result of infusion.

4.4 OPERATIONAL CONSIDERATIONS

Infusion from the Face

Any method of infusion which is conducted from the face will almost inevitably interfere negatively with productivity even when every effort has been made to optimize the coordination of production with infusion. Interference will arise not only from the additional work which has to be completed but from increase in the complexity and amount of equipment handled and stored at the face, problems with jammed drill tools and in-hole infusion equipment and potentially most seriously, from accidental water spillage.

Work conducted in France where continuous infusion from the face has been found to be effective is limited in its application to plough faces in thick (approximately 2 m) seams in which advance is relatively slow. In this system injection holes are drilled in the upper part of the seam (as close to the roof as possible) where they are not cut by the plough and can remain effective for several passes. There is a danger, however, of damage to the infusion pipe as the top coal falls in. This approach is not appropriate with shearer type power loaders, as used in the Sydney coalfield.

Despite the considerable operating problems associated with the infusion from the face, it remains the only feasible method in advancing longwall faces where no other access is available. The method is in widespread use in Europe as a dust controlling measure.

Infusion from Roads

Longwall retreat workings provide almost ideal operating conditions for infusion. Advance longwall working with advance headings driven more than thirty metres in front of the face, provides a similar opportunity for infusion but the congestion in advance headings can create severe operational difficulties.

Infusion from the long holes drilled parallel to the face in retreating panels can be carried out with no impact on productive operations. Holes can be drilled as the roads are driven or at any time thereafter and infusion can proceed continuously for extended periods of time until holes are cut by the face.

In hole equipment is normally cemented in place and consists of low cost, disposeable items. Installation of equipment in long holes requires trained personnel and careful supervision if proper water seals are to be achieved. This is not, however, a very large undertaking as the number of holes to be drilled and equipped is fairly small when compared with face infusion.

Monitoring of the infusion water flow and pressure has been conducted on most experimental installations and is routine on most full scale infusion projects. Continuous infusion at low flow rates and pressures may be in operation for months in advance of the face. In such cases fail safe mechanical/electrical controls and remote monitoring of pressure and flow have been used. These systems are designed to shut off water supply when pressure drops or unusually high rates of flow are measured. The objective being to protect against channelling of the water in the seam, short circuiting of water around the cement grout and failure of pipes and hoses in the roadway.

4.5 INFUSION POTENTIAL IN THE SYDNEY COALFIELD

Installation of water infusion systems even on an experimental basis should be preceeded by a detailed examination of the potential costs/benefits and comparison of these with costs/benefits of alternate dust suppression or dust avoidance measures. Careful analysis of the necessity for water infusion will require a detailed knowledge of the present quality of mine air at the working places. This should include a dust source analysis which identifies the relative proportions of respirable dust generated by each operation at the face. The USBM has reported several such studies in various US collieries

which have difficulty in achieving compliance with air quality standards (Jankowski). These studies identified not only improper dust suppression at the shearer as an important factor but the support advance, lack of dust control at the breaker/stage loader and poorly structured cutting sequence as major causes of non-compliance. If after evaluation of present dust suppression techniques in the Sydney Coalfield it can be ascertained that successful water infusion offers a potential cost saving and environmental benefit over improvements to existing dust control techniques, the method should be implemented on a trial basis.

The objective of a water infusion project should be to demonstrate a sustained reduction in respriable dust levels at identified working places where present systems are unable to ensure compliance or safe dust levels. It will be essential that water infusion is feasible without disruption of the production cycle and desireable that the infusion assists in coal cutting or environmental control to the extent that productivity can actually increase. In those working places where dust is adequately controlled by present systems it is unlikely to be cost effective to implement water infusion as a replacement for existing methods.

Geological considerations which affect the applicability and effectiveness of water infusion as a dust control measure are many and inadequately investigated even in coalfields where the method has been employed for decades. Parameters which undoubtedly play a part in determining the effectiveness of water infusion are the porosity and permeability of the coal, roof, floor and in-seam rock bands. Porosity and permeability as far as infusion with water is concerned are functions of fracture density, cleat spacing and definition, coal rank, inherent mositure of coal in situ, inherent mositure capability of the coal, depth of burial, joint in fill material, coal and rock wettability, existence of strain induced by mining and the existence of methane as a compressed gas in the coal and rock. No satisfactory model exists for analysis of these variables to determine the theoretical effectiveness of water infusion. The complexity of the problem is amplified

by observations which indicate that there is no clear correllation between the amount of water infused and effective reduction in dust produced in the workings.

Prince Mine

The retreat faces at the Prince Mine provide an operating environment in which long hole, long term infusion may be applied from holes drilled parallel to the face.

The main cleat at approximately 54^{o} to the face may cause some increase in flow in this direction as shown in Figure 4-4 and consequent uneven infusion of the coal mass. Conversely the permeability/infusibility of the coal in the direction of the secondary cleat and the effects of the pressure wave will tend to mitigate against fast flow of water through the primary cleat and could possibly result in a fairly even distribution of water provided the infusion flow is maintained until the face cuts the infusion hole. That is after the zones of compression and stress relief have passed the hole location. A series of holes of difference lengths may be found to give the best results in terms of complete face coverage.

The soft nature of the floor will require a careful and continuous monitoring program to determine as early as possible during the infusion if any problems are likely to occur. Roof conditions are not expected to deteriorate but careful observation of the effects of infusion on the roof will have to be made.

Infusion testing should be planned in conjunction with a program of coal moisture sampling at the face and rib and a detailed dust source analysis before, during and after mining through the infused zones.

Lingan Mine

Infusion can be carried out in holes drilled from the face in advance mining. This method has been used extensively in Europe and tested in North America with varying success. The major drawbacks of the method are interference with the production cycle and short infusion time on shearer faces where equipment must be removed from the holes before mining can proceed.

Nonetheless, in those faces where dust is a problem which has not been overcome by conventional methods and where there is time for installation of infusion equipment between production shifts, infusion from the face may provide a significant improvement in dust conditions at a reasonable cost.

Face infusion will require the acquisition of a number of infusion pipes and packers and a considerable amount of plumbing at the face to provide the required number of spigots to which injection hoses may be attached.

It will be necessary to experiment with holes of difference lengths and drilled in different orientations to achieve optimum infusion. There is good potential for a series of holes drilled at right angles to the primary cleat to be more efficient than holes drilled straight ahead from the face.

Infusion will require detailed scheduling of the mining and maintenance cycle to accommodate drilling infusion holes, installation of pipes and packers and time for infusion. For a typical face advance/shift of 1.5 m, an infused zone 6 m deep would take 4 shifts to mine through. Depending on the rate of evaporation at the face and the flow characteristics of the water in the fracture system and the ability of the coal to absorb moisture, this may provide a dust suppression effect. It is probable however that the water content of the coal would have approached inherent moisture by the fourth mining shift with consequent reduction in dust control. It is likely that infusion will have to be reapplied every day (assuming time is available

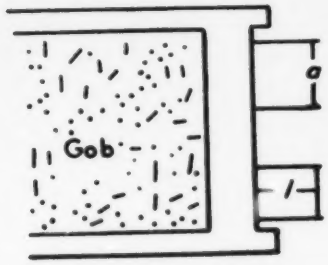
between cutting shifts) through short holes and every weekend through longer holes to maintain a continued dust suppression effect.

Infusion from the face on these advancing faces is feasible but the cost in equipment and labour will be significant. During initial trials, the condition of the roof, floor and face will require carful monitoring to detect any detrimental effects of water and any channelling of infusion water out of the face. A dust source survey and coal moisture survey should be implemented before during and after infusion trials.

Remote infusion from the intake road in an adjacent and preceeding panel would be feasible in the Lingan mine. This method has the advantage of eliminating interference with production at the face and could be carried out using the same basic techniques as described for the retreating panels at Prince mine. Additional attention would have to be paid to the drilling for remote infusion as the holes would have to remain in the seam at lengths of up to 180 m. Accurate drilling of holes this long can be achieved fairly efficiently using borehole surveys and careful directional control of the drill string.

The major disadvantage identified for remote infusion is that it can only be carried out for as long as the upper panel road is open. The lower face is usually about 800 - 1000 m behind the upper face at Lingan, and thus infusion would have to be abandoned about 1 year before the completion of the lower face when the equipment was withdrawn from the upper face and the panel sealed. Installation of infusion equipment in the last 1000 m or so of the road and control of the infusion from outside the sealed panel is a possibility but the pipework required would probably be prohibitive since remote electrical control in an uninspected area would not be permitted by the mining regulations.

The method does have potential for application over about two thirds of a panel life and this justifies its consideration.



SHALLOW INFUSION

l = Daily advance + 0.5 m

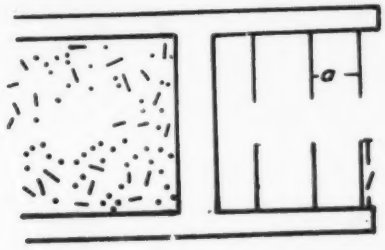
a = 1.5 to 2.0 × l

DEEP HOLE INFUSION

l = + 12 m.

a = 1.5 to 2.0 × l

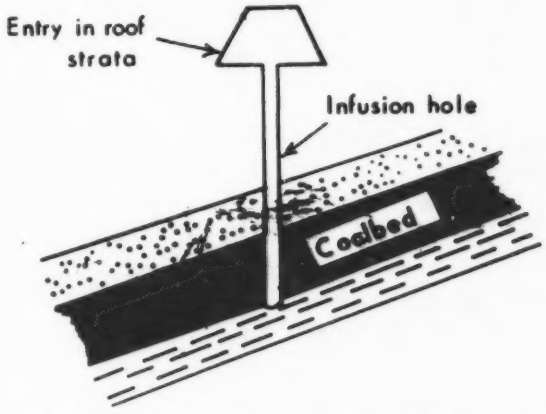
A - FACE INFUSION



l = 20 - 79 m

a 20 - 49 m

B INFUSION FROM ADVANCE ROADS



C - INFUSION FROM ENTRY IN ROOF STRATA

FIGURE 4-1

METHODS OF WATER INFUSION

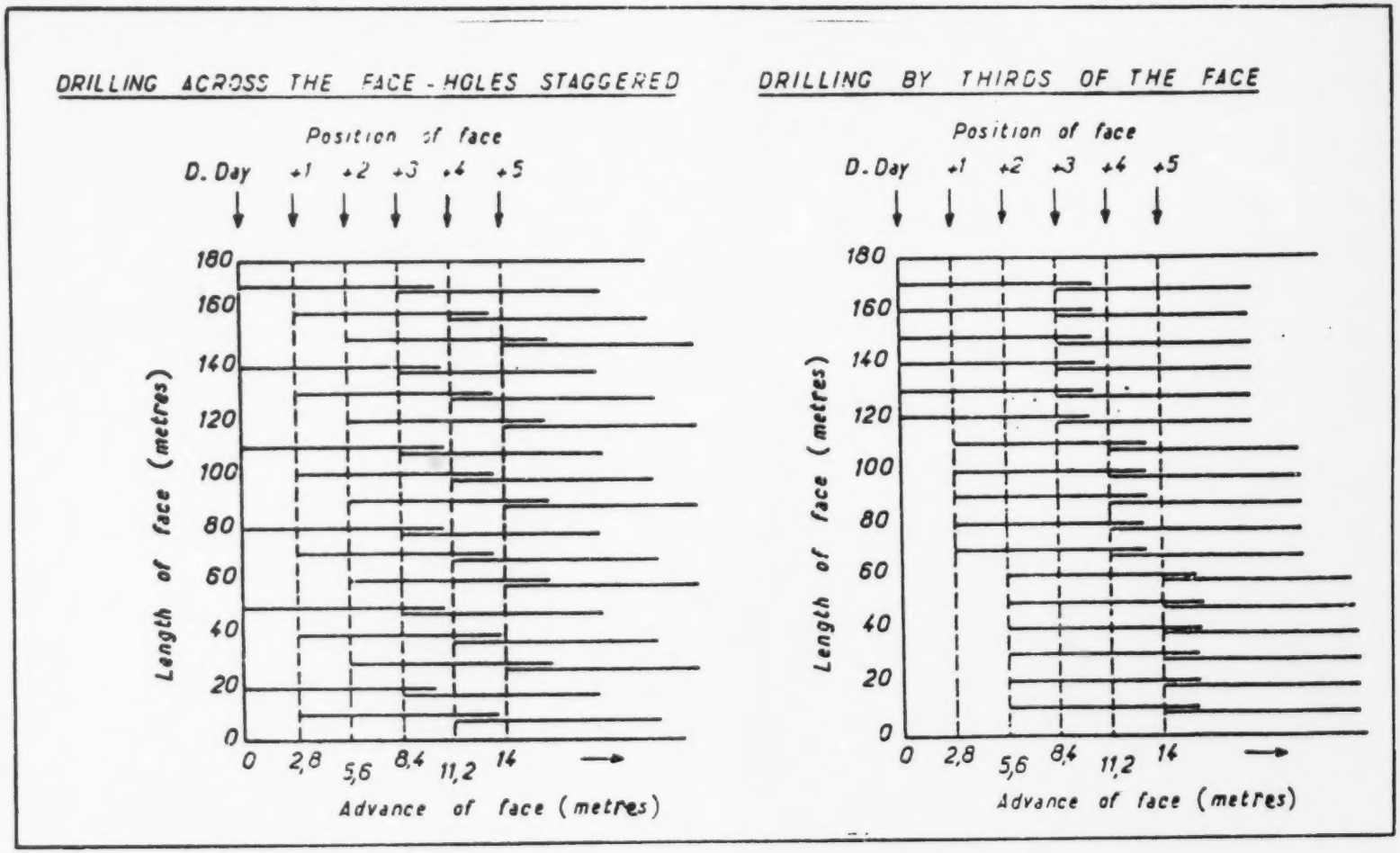


FIGURE 4-2

METHODS OF INFUSION FROM THE FACE

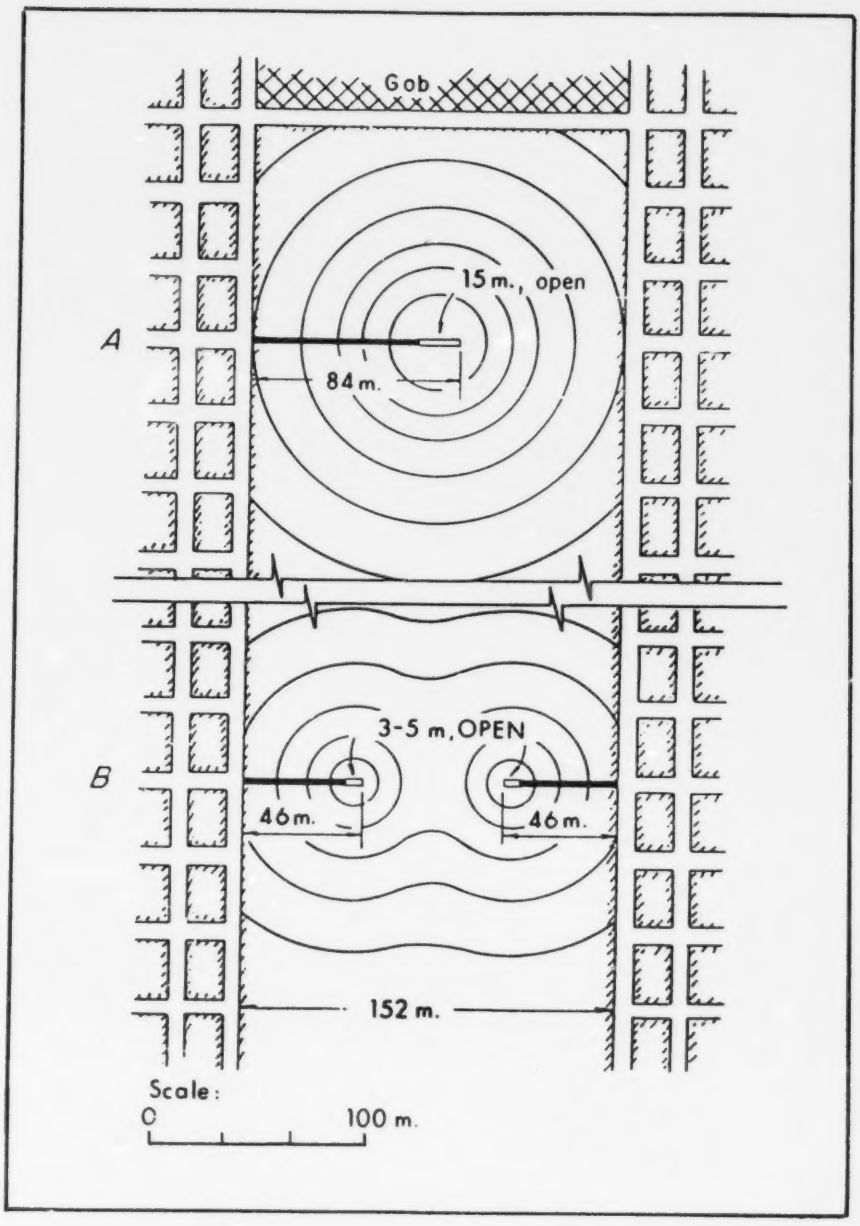
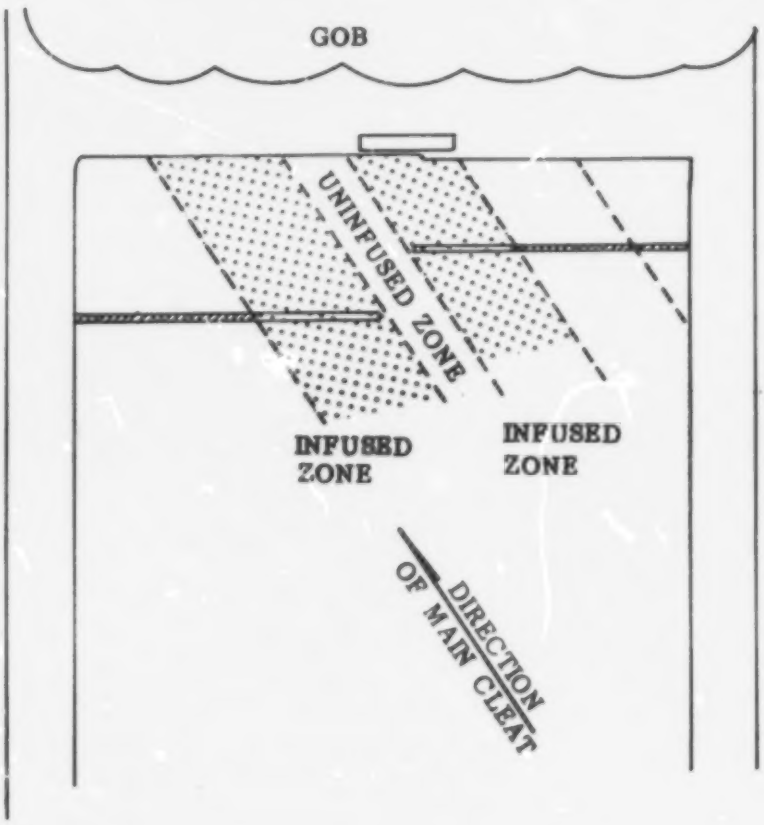


FIGURE 4-3

INFUSION OF RETREAT LONGWALL WITH ONE AND TWO HOLES



DIAGRAMMATIC - NOT TO SCALE

FIGURE 4-4

DIRECTIONAL MOVEMENT OF INFUSED WATER IN A LONGWALL PANEL

SECTION 5

WATER INFUSION TECHNOLOGY

5.1 INTRODUCTION

This section of the report examines aspects of water infusion technology from the perspective of the process of infusion, equipment used, the operation of an infusion program, the economics and the results of infusion.

The information presented was selected to describe the processes and equipment which may have applications in the Sydney coalfield. A brief discussion of the wetting action of water on coal is included, as is a description of the action of surfactants which may be used to enhance the wetting action. The need for test work to determine the wetting properties and infusion properties of the Sydney coals is emphasized.

To enable examination of the operating constraints of a water infusion program, a set of assumptions has been used to develop hypothetical time and work schedule for infusion at the face and for infusion from the roads. The economics of water infusion have been discussed and the cost centres are identified.

5.2 PROCESS TECHNOLOGY

5.2.1 Properties of Infusion Fluid

Viscosity

For all practical purposes as far as water infusion is concerned, the variation in viscosity of water with change in temperature and pressure may be ignored.

The use of additives which modify the viscosity may have some potential applications as an aid to retention of infused water in seams which tend to drain rapidly. Such additives could be mineral or organic and form a soft gel which would not drain from the fissures of the seam. There are no reports in the available literature of actual use of viscosity modification but some mention of its potential has been made.

Surface Tension and Wetting Action

The surface tension of water at a water gas interface and the adhesion tension at a water solid interface are measures of characteristics which determine the wettability of the solid by the water. Bituminous coals are commonly hydrophobic, that is they tend to reject water from their surfaces. This characteristic of bituminous coals is commonly exploited in the floatation process, where coal particles are attached to air bubbles circulating through a pulp of coal and water and thus are separated from high ash particles which are not so readily attached.

The hydrophobic nature of coal mitigates against effective wetting of coal for dust suppression and inhibits the penetration of infusion water into the coal mass. Wettability of coal (and other solids) can be visualized in terms of the contact angle which is formed at the coal/water/gas interface (Figure 5.1 a & b). The forces acting at the interface are shown in Figure 5.1c. Adhesion tension (AT) is defined in terms of these forces as follows:

$$AT = \sigma_{gs} - \sigma_{ls} = \sigma_{lg} \cos\theta_{lg}$$

where:

σ_{gs} = interfacial tension between gas and solid

σ_{ls} = interfacial tension between liquid and solid

σ_{lg} = interfacial tension between liquid and gas; and

θ = contact angle measured through the liquid phase.

A positive adhesion tension ($\theta < 90$, $\cos\theta > 0$) indicates that the liquid phase preferentially wets the surface and will tend to spread out over the surface to coat as large an area as possible. The magnitude of the adhesion tension is a measure of the surface energy of the system.

Where wetting of surfaces occurs in narrow fissures, such as the cleat in a coal seam, capilliary pressure will exert an effect on the spread of fluid. Capilliary pressure will act against the flow of water into a fissure when the contact angle is greater than 90°. This is readily visualized from the diagram in Figure 5.2 and can be expressed numerically for a simple capilliary tube by the following:

$$P_c = \frac{2\sigma_{LG}\cos\theta_{LG}}{r}$$

Where:

P_c = capilliary pressure
σ_{LG} = interfacial tension between liquid and gas
θ = contact angle measured through the liquid phase; and
r = radius of capilliary tube

The capilliary pressure can be seen to be inversely proportional to the dimensions of the fissure. Thus for very small openings, the pressure will be large. If the capilliary pressure works against the flow of fluid into an opening, this pressure will have to be overcome by some external pressure. This has significant practical importance and is one reason why it is often desirable to use a surfactant (wetting agent) to lower the surface tension of infused water. If the meniscus can be altered to produce a contact angle of less than 90°, capilliary pressure can be made to work in favour of the infusion presure.

Methane or air which exists in the fracture system of the coal may be said to preferentially "wet" the coal surfaces if the coal is highly hydrophobic.

As infusion water is introduced into the fracture system, the gas will tend to be confined to the smaller fractures while the water will occupy the larger ones. The saturation/capilliary pressure relationship is described and used in oil and gas reservoir engineering where reservoir volume is required. For water infusion, the relationship has importance in as much as the infused water will tend to drain readily from the large fractures while the smaller fractures will remain dry. Practically, water may migrate quickly to the lower plies of the seam or run from the face and rib. When the coal is broken at the face, there will be few wetted surfaces on which dust can be entrained.

Rate of Evaporation

Evaporation of infused water from the face or rib can significantly reduce the amount of water available for dust supression. In hot mines where large quantities of air are sweeping an infused face, the moisture content of the coal can decrease very rapidly.

Attempts have been made to slow the rate of evaporation at exposed surfaces by adding hydroscopic salts to the infusion water. (Salt addition also tends to reduce the surface tension of the water). Calcium chloride has been used in French and German mines (Deprez 1978, Becker 1977) as an anti-evaporant. The effectiveness of this salt addition cannot be ascertained from the available literature but the French results were described as "characterized by wide variation".

Minerals Dissolved from the Seam

The nature of the infusion water will almost always be altered by the dissolution of minerals from the seam and perhaps more importantly, adsorption by the seam of added chemicals from the water. The action is complex and may be visualized as a combination of ion exchange processes, straightforward solution or precipitation processes and carbon filtration

through a bed with moderately fine pore sizes. No firm data are available to evaluate the potential effects of dissolved minerals.

5.2.2 Pressure, Volume and Rate of Infusion

These variables are not related in any simple way as far as their overall magnitude in water infusion is concerned. For very short time periods, a linear relationship between pressure and rate of infusion may exist but studies show (Charbonnier 1966) that invariably the rate of flow at constant pressure decreases with passing time. The isobaric curves in Figure 5.3 show the change in flow rate at constant pressure for a number of seams in France.

The total volume of water infused is easily measured by simple flow meters and can be recorded as either an accumulated volume or a series of flow/time measurements from which an infusion profile can be developed. Infusion profiles which record pressure and flow variation with time can be used to evaluate and control the progress of infusion. When a number of records for the seam being infused are available, they will permit analysis of the infusibility of the seam and in conjunction with dust survey data, should be used for planning future infusion practice.

Pressures at which infusion is commonly conducted vary from the mine water system pressure (typically up to 2,000 kPa) to very high pressure delivered by infusion pumps (up to 50,000 kPa). The selection of infusion pressure for a particular seam should be based upon the following considerations:

- depth of seam
- length of hole to infusion chamber
- friability of the coal seam
- existence of major fissures, faults or other discontinuities
- proximity of extraction operations
- time available for infusion
- desired infusion quantity

- wettability of the coal by infusion fluid with and without additives
- distance between infusion holes
- availability of suitable pressures from mine water system
- availability of pumping equipment

The infusion probes and method of hole sealing should be selected to accommodate the desired pressure.

Infusion from the roads ahead of a retreating face has been successfully accomplished in France at 1,500 to 3,000 kPa pressure with flow rates as low as 0.5 to 3.0 l/min over periods of 2 to 3 months (C. Frogier et al 1974). French experience with infusion from the face indicates that pressures from 8,000 to 10,000 kPa should be used to provide sufficient water in the available time. Studies carried out in Germany indicate that for infusion from the face, flow rate of up to 80 l/min are obtained at pressures up to 35,000 kPa, the infused water amounting to approximately 10 l/m^3 of coal at which level satisfactory dust suppression can be obtained. In workings with advanced gate roads (geometrically speaking these are comparable with retreat faces), where longer times are available for infusion, pressures and quantities are controlled to allow infusion rates of up to 10 l/min.

A series of simple experiments should be conducted to assist in establishing a range of pressures which should be suitable for a full infusion trial on a working face in the Sydney Coalfield. The objective of the experiments should be to develop a family of curves for flow rates versus time for a range of pressures. The initial experiments should be conducted away from a production face in an area where geological conditions approximate those in operating areas and using holes of length similar to those proposed for full face trials.

5.2.3 Distribution of Infused Water

Factors affecting the distribution of infused water have been discussed from the geological standpoint in Section 2 and other factors have been mentioned in Section 4 and the preceeding parts of Section 5. Detailed studies to measure the actual distribution of water have been carried out in France (Schwartzmann 1972). This work was conducted in the Nord-Pas-de-Calais coalfield where 50% of the production was being infused. A detailed coal moisture survey was initiated, the face, rib and solid coal in the test area was sampled before infusion and analysed to determine inherent moisture. After infusion and as mining progressed in a retreating panel, the face was sampled every day. The face sample interval varied from 4 to 10 metres. In practice only one coal ply was sampled but it was recognized that a more rigorous system would have sampled each coal ply. The results were plotted on a plan and an iso-moisture map was drawn up, Figure 5.4. A statistical analysis of the results produced data from which areas likely to experience a significant moisture increase could be predicted, Figure 5.5.

Early work in the USA (Cobb 1969) described the anisotropic distribution of infused water in a seam containing a rock band which was largely impervious. The rock band was believed to inhibit vertical migration of the water and thus assist in directing flow horizontally outward over a large area of the seam.

Anisotropic distribution of water has also been attributed to differences in directional permeability which was related to the cleat definition and orientation.

5.3 EQUIPMENT AND MATERIALS

5.3.1 Drills & Drilling

The drills identified in the literature as being suitable for water infusion holes are generally those machines which are in use for other purposes in the collieries concerned.

Generally speaking hand held rotary drills are suitable for holes drilled from the face to depths less than about 6 metres. Longer holes in face infusion and all holes used for infusion from the roads require mounted drills.

In mines where methane drainage is regularly practiced the methane drainage drills are frequently used to drill long holes for infusion from the roads. Horizontal holes or holes parallel to bedding in coal are seldom used for methane drainage purposes although the method has been tested in a number of US collieries and implemented occasionally elsewhere (Stephenson 1977).

Drilling long holes in coal requires careful set up of the machine to maintain the bit in the seam. A 1^{o} error in set up angle will result in a vertical error of 1.75 m for every 100 m drilled, similarly a vertical deviation of the bit by 1^{o} will cause the hole to run into the roof or floor of a 2 m seam within 58 m if the hole is started at the centre of the seam.

In highly gassy seams the production of methane from long holes can increase substantially during drilling. Cervik (1975) estimated that the methane flow from horizontal holes drilled in virgin Pittsburgh coal increased at a rate of 0.02 m^3/s per 30.48 m of hole. To cope with this the U.S. Bureau of Mines developed a stuffing box from which methane could be extracted and conducted away from the working area. It is considered unlikely that the seams in the Sydney coalfield will produce troublesome quantities of gas from holes drilled for water infusion. If the quantity of methane produced is sufficient to warrant concern, the standard practice used for methane drainage holes should be adopted to confine the gas.

Table 5.1 is a summary of the types of drilling equipment used in Europe and the USA. A wide variety of hole sizes, steel types and accessory equipment is used but the most common equipment for long holes consist of a post mounted, power feed hydraulic drill of less than 7.5 kw (10 HP) rotation power, round drill pipe with flush joints in lengths to suit the bed of the available drill and double or triple wing, drag bits of common design. Most water infusion long holes are drilled with water.

Hole stabilization has been achieved in the US by use of long (approximately 3 m) stabilizers placed behind the bit (Cervik et al 1977). The stabilizer has a diameter slightly smaller than the bit and allows for clearance of cuttings through an annular space between the body of the stabilizer and the central drill rod. Correction of hole deviations has been described by Cervik (op cit), short centralizers were used to correct upward deviation and slow reaming passes were used to correct downward deviation by allowing the bit to wear the bottom of the hole. These techniques, in conjunction with borehole surveying were used to complete very long infusion holes and are not thought to be necessary for infusion in the Sydney Coalfield where holes will be relatively short.

Recent work in Germany (Becker 1983) indicates that a hydraulic turbine drill is being developed to drill short holes very quickly. Mention is also made in this work of a drill which is transportable on the face conveyor. Few details are available on these new developments.

TABLE 5.1

DRILLING EQUIPMENT IN USE FOR WATER INFUSION

Country	Drill Type	Hole Dia.	Hole Lengths	Bit Type	Steel Type
France	Montabert Type RA 26D Rotary, Post Mounted	43-50 mm	30-60 m	Wing Rotary	Round 35 mm O.D. 25 mm I.D.
France	Turmag P111/1V Rotary, Post mounted (3 kw @ 200 rpm, 1.9 kw trav)	45 mm	50-70 m	Wing Rotary	Lerat Martin Hoiow grooved 22 x 32 mm
Germany	Turmag PIV/6 or IV/6K Rotary, Post mounted (4-5 kw rotary, 3 kw traverse) weight 460 kg	up to 95 mm	17-59 m	Wing Rotary, Diamond, or Roller Cone	Round, Smooth, 52 mm OD 1.1 m to 1.8 m screw coupling
USA	7.5 kw Post mounted manufacturer not identified	152.4 mm	61 m	Not described, probably 3 wing rotary	Auger type 1.8 m lengths
USA	Hand held manufacturer not identified weight 25 kg	73.5 mm	Normally short, may be used for long holes if used mounted	3 wing rotary or roller cone	Smooth, round (EW, flush joint drill pipe) 3 m lengths
	Post mounted elec/hydr. mfg not identified approx. 7.5 kw rotary	73.5 mm	long holes	3 wing rotary or roller cone	EW, flush joint
UK	Hand held	42.8-49 mm	less than 6 m	Not described	Not described
	Victor drill type not identified	42.8-49 mm	greater than 6 m		

5.3.2 Fluids

Infusion is conducted with water which may contain additives to modify the wetting capability or evaporation rate of the infused water.

A study of wetting agents was conducted by the USBM (Zeller 1983). The effectiveness of several agents was evaluated by measurement of the weight of fluid drawn up by capilliary rise into a column of crushed coal.

Zeller concluded that:

- The indiscriminate use of surfactants must be avoided
- Some coals which are readily wettable by water alone become hydrophobic in the presence of some surfactants.
- Surfactant mixtures apparently retain the characteristics of their components.
- Any expected benefits from surfactant should be verified (by testing with the specific coal and mine water).

Table 5.2 lists some surfactants tested and their surface tensions at 0.1% concentration in water, Table 5.3 presents capilliary rise test results for a Utah coal and 15 surfactants. The manufacturers of the surfactants are listed in Appendix C.

European, particularly German, work has concentrated on the use of hydroscopic salts as additives to infusion water.

TABLE 5.2

PHYSICAL PROPERTIES OF SURFACTANTS IN 0.1% SOLUTION WITH WATER

Liquid	Surface Tension uN/mm	Viscosity cP
Distilled water	72	.93
F-65	31	.93
Compound MR	34	.92
CF-54	33	.92
Tergitol MPX	34	.98
Aerosol GPG	29	.96
Aerosol OT-75	29	.97

TABLE 5.3

CAPILLARY RISE TEST RESULTS FOR UTAH COAL

	Coarse Grid		Fine Grind	
Liquid[1]	Rise Height mm	Weight Gain pct	Rise Height mm	Weight Gain pct
Aerosol MA-80	25	32.5	25	18.0
Surfynol 465	13	21.8	6	10.3
Aerosol AY-65	25	20.1	25	10.3
Aerosol OT-75	19	17.0	9	10.1
Monowet MO-70E	15	15.9	8	9.4
Dustallay	10	15.1	10	6.9
Pluronic L-72	13	14.9	7	6.4
Gemtex SC-40	11	14.2	11	8.8
Product 55	15	12.3	15	6.4
Tryfac 610-K	5	11.8	3	6.0
Aquadyne	9	11.8	3	5.1
Local[2]	5	10.1	5	6.4
Coal Dyne 100	10	9.9	10	9.0
Compound MR	7	8.8	5	6.8
D-Dust	9	6.1	4	6.4
Isopropyl alcohol	25	32.7	25	28.9

[1] Surfactant concentration in distilled water was 0.1 pct.
[2] Locally available surfactant near mine, source unknown

Calcium chloride and magnesium chloride have been used to improve the effectiveness of water infusion. In longwall infusion tests concentrations of up to 0.2% of $CaCl_2$ lye was added to the infusion water by a proportioning device (see Section 5.3.3). Solid cartridges of $CaCl_2$ have also been used to administer this additive by slow dissolution of the solid which was placed in the hole before commencing infusion. Dust counts from working places where $CaCl_2$ was used showed improvements when compared with pure water infusion but no numerical data were reported (Becker 1971). Use of hydroscopic salts is not normal practice in the German coal industry but the practice of infusion is very widespread (92% of coalfaces in 1982-1983). However, current German research seems to be increasingly oriented toward improved control systems, drilling methods and organization rather than infusion fluid additives.

5.3.3 Pumps

It has been pointed out in previous sections that the use of pumps to provide the required infusion pressures is dependent on the nature of the coal. Where satisfactory results can be obtained using mine supply pressures, this is the preferred method.

Positive displacement piston pumps are most frequently used for water infusion work in all parts of the world. The USBM has reported pump characteristics of units used in testwork up to 1977, these are given in Table 5.4.

The wide variety of equipment in use around the world can be judged from Table 5.5. No one manufacturer or capacity of pump can be said to be typical. For initial test work a unit with a high degree of flexibility in capacity and pressure should be selected so that a large range of infusion pressures can be experimented with. (Note: manufacturers data from Germany has been requested and is expected to be available early in 1985).

TABLE 5.4

INFUSION PUMP CHARACTERISTICS
(three-piston)

Piston Size (mm)	Maximum Pressure (kPa)	Flow Rate (l/min)
50.8	6,000	163.7
44.5	7,860	122.7
38.1	10,690	100.0
31.8	15,170	63.6
25.4	24,130	45.4

TABLE 5.5

PUMPS USED FOR WATER INFUSION

Country	Manufacturer & Type	Pressure Range (kPa)	Flow Rate (l/min)	Auxiliary Equipment
France	Jerusel 30	Not available		
	Atlas 5HP	to 14,480		2 pumps used in series to give non pulsating delivery
Germany	Hauhinco EHP 3K10	5,000-50,000	6-100	Surge tank to control pulsating delivery
USA	Not identified	2,826 2,206	37.8 32.2	
U.K.	3CYL ram	41,368	90.9	
	65 HP T50 Gullick	24,821	71.6	

When additives are to be supplied with the infusion water, metering pumps or other proportioning devices are required to move the additive from its container into the infusion stream. A large scale proportioning device has been described by Becker (1972 and 1977) for addition of $CaCl_2$ into infusion water. A schematic of this device is shown in Figure 5.6. Surfactant additives are used when required in small, accurately measured quantities. Metering pumps may be successfully used for this purpose. They frequently consist of small capacity, positive displacement pumps which are driven from the shaft of a main infusion pump through a gearbox/speed reducer. The desired proportion of additive can be pre-set by adjusting the pump displacement or by changing the gear ratio of the speed reducer.

In all the test work on water infusion conducted during the last twenty years and on most permanent installations in Europe, volume and pressure measuring equipment is used. Recently volume and pressure control devices have been developed which work automatically or allow for remote control from a control panel. Many of the measuring devices used are standard pressure and volume meters which are commonly available on most working mines where hydraulic supports are in use. In Germany where specialized infusion equipment has been developed, combined volumeter/manometers are available for remote transmission of data. Quantity control valves for use in multiple hole injection from a single pump are also manufactured in Germany (Note: information and specifications requested).

Control systems for infusion using the mine water supply pressure have been developed in France. The objective of these systems is to allow monitoring and regulation of the rate of infusion and to provide automatic shut down if accidental water leakage occurs during periods when the mine is not fully manned. Automatic shut down is particularly important when long term continuous infusion is applied and a flood risk may arise from leaks in the water supply, breakdown of a hole seal or sudden fissuring of the seam.

Two control systems have been described in the literature, the first has some severe design shortcomings in that it can be activated by unusual but necessary water demand underground (to fight a fire for example). Control systems of this type should be avoided. A more sophisticated control system, developed by Schlumberger, operates on the area supply, it will shut off the water in case of leaks up or downstream from the gauage, gives an alarm at the surface and can be used to measure and record water infusion quantities. The Schlumberger system is shown in Figure 5.7.

5.3.4 In Hole Equipment

The length of the hole to be infused and the duration of infusion are the most important criteria to be considered when selecting in hole equipment. Infusion from the face normally requires short holes and short time periods for infusion, infusion from the roads requires much longer periods of time.

Short hole infusion has been carried out using mechanical hole packers (screw type), pneumatic and hydraulic packers and self inflating hydraulic packers. Only self inflating hydraulic packers are commonly in use today. These devices are known as "Petrometallic" infusion probes in France and under various trade names in Germany. They consist essentially of a high pressure reinforced hose which is designed to expand diametrically under pressure. Expansion is limited either by a woven nylon or metallic reinforcing layer which allows expansion to a predetermined maximum or by the confines of the infusion hole in which the probe is installed. Water is applied to the probe from the infusion supply (pump or mains), flow through the probe is restricted at the inside end by a small orifice and the probe engorges until it seals the hole. The probe remains sealed in the hole so long as a pressure drop exists through the discharge orifice and so long as water is supplied to the probe. At the completion of infusion the water supply is shut off, the probe deflates and can be easily removed.

Self inflating infusion probes are available in a range of sizes and pressure requirements. The flow through the probe is controlled by selecting sizes for the orifice and controlling applied pressure. In some applications in virgin coal where the permeability was low, problems were encountered with low flow rates which eliminated the pressure drop across the orifice and caused the infusion probes to eject violently from the hole. These problems have not been reported for applications at the face where permeability is usually good and where stress relief fissuring causes roughness or ridging of the hole which gives a good grip on the rubber casing of the probe. Two designs for probe flow control orifices are shown in Figure 5.8, specifications for probes are provided in the same figure.

Early attempts at long hole infusion used mechanically applied seals which comprised of rubber rings. These were expanded to the walls of the hole by screw mechanisms which compressed the seals longitudinally. Success with this equipment varied but the most common problem encountered was by-passing of the seal by infusion water. Pneumatic and hydraulic packers spaced along the hole to form a series of seals overcame the by-pass problem but were expensive and often impossible to recover. Cement seals were the obvious solution to the problem and this type of seal is now ubiquitous where long hole infusion from the roads is practiced.

Many different methods of applying cement seals have been reported but all have the same objective which is to provide a cheap easy to install seal which is effective over the lifetime of the infusion process. Typical requirements of a cement seal are shown in Figure 5.9. The USBM cemented infusion seal is very cheap to assemble and install and reported to be effective. The components for the seal are normally available in any mine warehouse or can be easily obtained. The elements of the seal system are shown in Figure 5.10. The usual cement for infusion hole sealing is normal portland cement in a slurry comprising approximately 25 Kg cement and 30 litres of water, in some instances sand is added to increase the strength of the seal. Quick setting properties can be induced by addition of calcium

sulphate to the cement. A curing period of at least 48 hours should be allowed for cement to harden.

Cement may be injected into the hole from a cylinder by air pressure or by a cement pump (positive displacement grout pump is suitable as is a rubber stator, Mono type pump). The USBM packer automatically ensures that cement does not block the inside end of the infusion tube. Simpler cementing systems require careful application of the cement against a plug placed behind the open end of the water tube to ensure free passage of infusion water.

The optimum length of a cemented seal will depend on the condition of the coal in which it is to be placed. The seal must be placed so that the inside end is in solid coal inside the stress relief zone around the gate road. The USBM cements approximately 75% of the hole length for holes about 100 metres long, somewhat less for shorter holes. French practice is to seal a minimum of 17 metres and in Britain seals of 20 metres were successful for 30 metre long infusion holes.

In very gassy seams, methane may create bubbles and cavities in the cement (if an unconfined cement seal is used), this can result in ineffective sealing and should be avoided by using a confined cement seal as in the USBM system, Figure 5.10.

The use of resin sealing materials, similar to the resin grout used for rock bolting, has been proposed for water infusion. These materials are expensive and difficult to apply in long holes where pumps must be used. Resins which expand in volume by gas formation during curing, may have some limited application in sealing holes where methane is a problem. Generally speaking a portland cement grout applied with simple equipment will perform very efficiently and is preferrable to costly resins or inflatable packers for long hole, long term infusion.

5.4 OPERATIONS

Operating aspects of water infusion vary from mine to mine and often from face to face within the same colliery. It is vital on modern, high productivity faces to integrate the infusion process with all other operating functions to prevent interference with face productivity. Integration of water infusion with coal winning operations is more complicated for infusion from the face than for infusion from the roads. At collieries such as the Lingan mine in Cape Breton where coal winning is carried out on three 6 hour shifts each day, it may be impossible to effectively infuse the face without reorganization of the entire production schedule to maintain overall production levels. Individual face productivity will almost inevitably be reduced on the highest output faces in the mine because of the additional manpower required for drilling, installation and operation of the infusion equipment.

Evaluation of the time and manpower requirements of infusion from the face will require a technical evaluation of the infusibility of the seam so that estimates of infusion time, pressure and volume can be made. When the technical data relating to specific conditions in the Sydney coalfield are available, detailed organization planning can be carried out.

To illustrate the planning process, Norwest has assumed reasonable flow rates and volumes and developed the following hypothetical face infusion work schedule.

Assumptions

Face length	200 m
Seam height	1.8 m
Cutting shifts/day	3 x 6 hours
Advance/shift	1.5 m
Advance/day	4.5 m
Infusion rate/hole	10 l/min

Infusion requirement	10 l/m^3 coal (1%)
Hole spacing	10 m

Infusion Time Requirement Calculation

Coal volume/metre advance	=	360 m^3
Coal volume/day	=	1620 m^3
Infusion volume required/day	=	16200 l
Infusion volume/hole/day	=	853 l
Infusion time/hole	=	85.3 min.
		(use 90 min.)

Drilling and Installation Time Requirement Calculation

Hole length = 4.5 m + 0.5 m	=	5.0 m
Drilling time with hand held machine	=	5.0 min.
Move & set up time/hole	=	2.0 min.
Total time/hole	=	7.0 min.
Drilling time for 19 holes	=	133 min.
Set up at start of shift and take down at end	=	60 min.
Total time to complete drilling	=	193 min.
Infusion probe installation & connection/hole	=	5 min.
Infusion probe disconnect and store/hole	=	5 min.
Infusion gear set up and take down/shift	=	60 min.

Assuming a 2 man crew is dedicated to the infusion operation, the following schedule of work can be achieved.

Activity	Total Elapsed Time (minutes) #1 Driller	#2 Infuser
Shift start	0	0
Set up drilling equipment	30	
Set up infusion gear		30
Complete drilling	163	
Install 19 infusion probles		168
Take down drilling equipment	193	
Commence takedown of infusion gear	193	168
Completion of infusion on last hole	258	258
Completion of equipment take down	288	288

Total time for infusion = 288 minutes = 4.8 hours

From the schedule it is apparent that a two man crew could completely infuse a 200 m face through 19 holes 5.0 m long in less than a single working shift. The amount of unscheduled time is probably sufficient to allow for breakdown repairs on equipment and some regular maintenance. If infusion is conducted on the maintenance shift there would undoubtedly be some congestion at the face, work advancing pipe and services in the roads would require special consideration to ensure that power and water is available when required by the infusion crew.

The workmen will require some training to start the infusion program. Careful supervision in the early stages will help identify difficulties in the procedure and make sure that the men can and do carry out the required work. Each man in the crew should be trained to do all the required activities and the crew should be encouraged to work as a team. (Drilling by one crew or shift for infusion by another crew would probably lead to inefficient working and inadequate results from the infusion).

In the Lingan mine where infusion from the face may be applied and a 4 shift system is practiced, some faces are worked 3 shifts per day, the 4th

shift is the maintenance shift. This work schedule leaves enough time for an infusion crew to complete their work but time would be tight if the assumptions the above calculations are approximately correct and maintenance is proceeding at the same time.

Estimation of the operating requirements for infusion from the roads can be based on similar assumptions regarding the flow rate achievable and the desired volume of infused water:

Assumptions:

Face length	150 m
Seam height	1.8 m
Cutting shifts/day	3 x 6 hours
Advance/shift	2 m
Advance/day	6 m
Infusion rate (Average)	1.0 l/min
Infusion requirement	10 l/m^3 coal (1%)
Hole length	50 m (drilled from both roads)
Hole spacing	20 m
Sealed portion of hole	20 m

Infusion Time Requirements

Coal volume/hole	2,700 m^3
Water requirement/hole	27,000 l
Infusion time/hole	27,000 min. = 450 hours = 18.75 days
Distance ahead of moving face	112.5 m (ignoring nonproduction days)

The actual time required for drilling and installation of the infusion equipment is not critical to the integration of the work with production operations.

Drilling and installation can be carried out well in advance of mining (possibly at the same time as methane drainage work).

5.5 ECONOMICS

The economics of water infusion in terms of costs and benefits are difficult to quantify before a full scale trial has been conducted. In any case it will be virtually impossible to assign a monetary value to the benefits, the best that can be done is to determine whether the dust inhibition effects of infusion are comparable with the effects of improved ventilation or water spray equipment and to evaluate the comparative costs of alternate approaches to the problem.

Fortunately the costs of water infusion can be estimated with some degree of accuracy and in most environments if these costs are reasonable, the benefits obtained are considered worthwhile if the workplace can be made safer. If water infusion disrupts production activities to the extent that production drops below a desired level or if expansions in production/productivity cannot be accommodated, the cost would probably be considered too high and alternate methods would probably be sought to reduce the dust problem.

The direct costs of a water infusion program can be broken down into distinct areas:

- Equipment acquisition (ownership) cost
- Equipment operating & maintenance cost
- Manpower cost
- Consumables

These can then be detailed and subdivided for infusion from the face (FI) and from the roads (RI) as follows:

Equipment Acquisition Costs

	FI		RI
101	Hand held drills	101	Mounted drills
	Drill power pack (hydraulic)		Drill power pack (hydraulic)
	Drill steels & bits		Drill steels & bits
102	Infusion probes	102	Cement pump & hoses
103	Infusion hoses at face	103	Infusion hoses
104	Control valves	104	Control valves
105	Volume & pressure meters	105	Volume & pressure meters
106	Infusion pump	106	Infusion pump
107	Metering pump (for additives)	107	Metering pump
		108	Monitoring system (remote)

Equipment Operating & Maintenace Costs

	FI		RI
201	Hand held drill (oil & maint.)	201	Mounted drill (oil & maint.)
	Drill power pack (power & maint.)		Power pack (power & maint.)
	Steel (replacement)		Steel (replacement)
202	Infusion probes (replacement)	202	Cement pump (power & maint.)
203	Infusion hoses (replacement & maint.)	203	Infsuion hoses (replacement)
204	Control valves (replacement)	204	Control valves (replacement)
205	Vol. & press. meters (maint.)	205	Vol. & press. meters (maint.)
206	Infusion pump (maint.)	206	Infusion pump (maint.)
207	Metering pump (maint.)	207	Metering pump (maint.)
		208	Monitoring system (maint.)

Manpower Costs

	FI		RI
301	Infusion crew 2 man shifts/4.5 m advance	301	Infusion crew 4 man shifts/20 m advance

Supervisory Cost

	FI		RI
401	Daily supervision at the face	401	Daily monitoring of infusion equipment

Consumables

	FI		RI
501	Drill bits	501	Drill bits
502	Hose couplings, clamps & pipe joints	502	Hose couplings, clamps & pipe joints
503	Additives	503	Additives
		504	Cement
		505	Infusion pipe

The equipment requirements for infusion from the face are greater than for infusion from the roads, this together with the much higher level of manpower used per metre of advance, will tend to make face infusion more costly than infusion from the roads. If the cost of hole sealing in the long holes used in infusion from the roads can be kept low by using cheap components, the cost advantage of infusion from the roads is improved. The manpower cost for face infusion may be approximately twice that for infsuion from the roads.

5.6 RESULTS

5.6.1 Dust Control

In the majority of reported applications of water infusion some measure of dust control has been achieved. In German collieries where water infusion is mandatory it is not possible to compare dust levels on a before and after infusion basis and the relative importance of infusion and other dust combatting measures is not quanitified terms of dust control effect.

American experience with water infusion on an operating scale is limited but the test work done by the USBM provides some good indications of dust reduction effects which may be achieved. Regulations regarding acceptable dust exposure in the U.S. coal mining industry are considerably more stringent that those pertaining to the Sydney coalfield and with the increase in longwall installations in the U.S. during the last few years, it is apparent that several operations are not meeting regulatory dust requirements. There are no indications that those U.S. collieries with a dust problem are implementing the use of water infusion on a full scale basis.

British coal mines have used water infusion in their efforts to reduce dust levels in many different mines. Substantial variation in results exists from coalfield to coalfield and even from face to face. The most difficult coals to infuse effectively are the South Wales anthracites which have very low solid permeability and little cleat or fracture permeability. Interestingly these anthracite collieries were some of the first to attempt water infusion to overcome a serious dust problem despite having some of the most difficult coals to infuse. It is unclear whether infusion in these mines was truly effective in inhibiting respirable sizes of dust or whether an increase in comfort level due to lower levels of larger dust sizes was the result. It has been reported that infusion was more effective on low production faces than on high tonnage, mechanized faces and that this difference was due to the formation of stress relief cracks ahead of slower moving faces.

Table 5.6 shows a summary of some dust control effects reported from several mines in America and Europe. It is important to note that the cases reported often represent successful application of water infusion and that many unsuccessful attempts are not written up or published. The number and location of failures is unknown.

5.6.2 Strata Control

Where water infusion has been successfully applied, strata control has neither improved nor deteriorated in most cases. The most common problem encountered has been pooling of water in depressions in the floor and consequent lowering of the trafficability of the floor rock. Other difficulties reported include softening of fault or shear zone material. Neither of these difficulties are major safety concerns but preliminary examination of the effect of water on the roof and floor should be carried out before implementing water infusion.

High pressure infusion of water could have the effect of bursting the strata in advance of the face with consequent reduction in material strength. Proper regulation of infusion pressure and preliminary testing will substantially eliminate this potential hazard.

Some leakage of water from the seam into the roof may assist in softening some roof rock and actually assist in strata control. A sandstone and conglomerate roof in the Datong, Tonghua and Beijing coal areas of China has been successfully controlled by softening with high pressure water infusion which increases the caveability of the roof and prevents large areas from hanging up behind the face (Niu & Gu 1982).

There have not been reported incidents of serious strata damage due to water infusion for dust control in the European mines where the method is widely used. Between 2% and 8% of German collieries are exempt from

TABLE 5.6

DUST CONTROL RESULTS FROM WATER INFUSION

Country	Seam Infusibility	Infusion Type	Respirable Dust Suppression
France	Good	From the roads	73%
France	Moderate	From the roads	47%
U.S.A.	Moderate	Face (room & pillar)	25-50%
U.K.	Good-moderate	From the roads	52%
U.K.	Moderate	Face (advancing LW)	18%
U.S.A.	Good-moderate	From the roads	approx. 70%

using water infusion, some of this small number would undoubtedly have potential or actual strata difficulties which may be made worse by water infusion. Commonly, however, it has been reported that softening of in-seam rock bands occurs as a result of infusion and assists in cutting these harder units.

5.6.3 Productivity

Infusion from the face may impact adversely on productivity if coal winning time is reduced to accommodate the infusion process. Conversely where a face is operating close to or above the statutory dust levels and shut downs are frequent or men must be moved to the intake side of the shearer to reduce their dust exposure, the use of infusion may actually increase productivity. The increase will be most obvious for faces where other methods of dust suppression are not satisfactory and where production is suspended. Infusion may allow the reopening of these faces and their continuing operation in compliance with dust standards. Changes in the regulations which would impose more stringent standards on dust levels could create a situation where substantial production capacity would be made idle.

If other measure to suppress dust were not satisfactory in these circumstances, water infusion would be a very reasonable approach to solving the problem and would have a definite impact on productivity.

Increases in productivity due to softening of the coal or in-seam rock bands are a potential benefit of water infusion but are thought to be small and should not be taken into account in advance planning. Faster cutting or lower power consumption which may be a result of infusion will probably be more than offset by the delay time due to water leakage, equipment breakdown and additional congestion at the workplace.

The effect on the workforce of a better working environment may be a very worthwhile benefit of infusion. Reduction in the amount of visible dust will be immediately regarded as an improvement by the face workers and provided that this is not offset by other discomfort factors such as water dripping from the roof between supports, may at least increase morale if not productivity directly.

It has been reported that water infusion reduces the temperature of some working places by a significant amount. If this temperature reduction provides a more comfortable working environment, employee morale may also be improved.

5.6.4 Safety

A water infusion program should not introduce any additional or new safety hazard into the mining operations. All of the equipment used for drilling, pumping etc. should be approved for use in coal mines and will probably be identical in large measure to that already in use for other purposes at the colliery.

High pressure infusion requires training and supervision of personnel to ensure that equipment is properly maintained and used. Training should identify

potential hazards (for example, sudden release of an infusion hose from a hole may create a potentially hazardous situation if the equipment shoots out from the hole) and ensure that operators are aware of the capabilities and limitations of the equipment.

Handling portland cement or infusion water additives underground requires proper protective clothing (particularly eye and hand protection). All additives should be checked for flammability and toxicity before use underground and clearance for their use should be sought from the mines inspectorate. Operators must be fully instructed in the proper application, handling, and storage of toxic or flammable additives as well as special requirements in case of accidential spillage or contamination of personnel.

Strata control should not constitute a safety hazard if the infusion program has been properly designed, tested and implemented. The entire program should be monitored by a competent engineer and any signficant changes in roof or floor condition should be brought to the attention of the section foreman immediately and to the management as soon as practical.

The long term objective of successful water infusion is to reduce the amount of respirable dust to which the miner is exposed. In conjunction with conventional dust suppression measures, water infusion may provide a substantial benefit in this regard and help eliminate a major safety hazard.

5.6.5 Methane

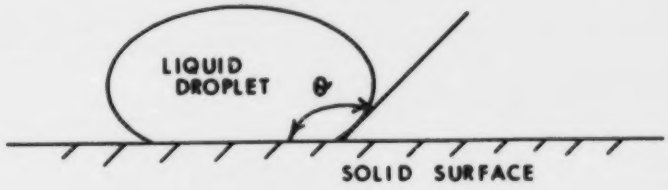
In the advancing workings at the Lingan mine a procedure of methane drainage and methane extraction is in operation. The boreholes through which the methane is drained are drilled upward over the gob at an angle of about 60° and downward at about 45° beneath the gob. It has been found that signficant amounts of gas can be removed through these holes and thus be prevented from entering the workings. Water infusion would have little if any impact on the release of methane from strata above and

below the seam and consequently the methane drainage program would not be affected.

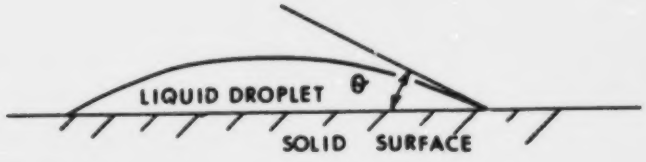
The release of methane from the seam in advancing workings may be impacted by the use of water infusion. It is possible that a thoroughly infused face would produce less methane per ton of coal produced as a result of the water barrier effect described in Section 4.3 combined with the displacement of methane by infusion water. The rate at which methane is produced during winning operations (when cutting infused coal) may be reduced but as infusion is taking place, the methane would be displaced into the workings, resulting in a redistribution of the time at which gas accumulations would occur but no overall reduction in the quantity methane released.

In retreating faces there is a more likely chance of reducing methane released during cutting. The gas can be displaced by water and will tend to migrate out of the coal seam to the rib or into the adjacent strata if infusion is carried out well in advance of the face. This would not eliminate the need for methane drainage from the gob and may indeed increase the amount of gas in the gob by virtue of displacing it from the seam prior to mining.

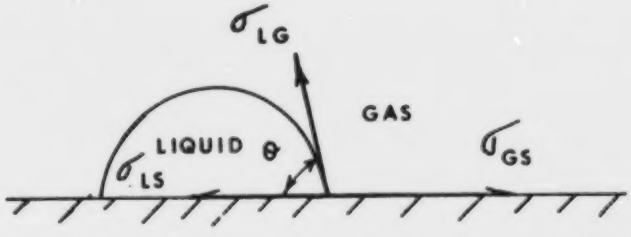
Trials of water infusion in the Sydney coalfield should include monitoring of the methane released in the test panel, before, during and after the infusion to determine how the gas distribution is being affected by infusion.



a) Contact Angle = $\theta > 90^{\circ}$, Low Wettability,
Examples: Pure Water/Bituminous Coal, Mercury/Clean Glass



b) Contact Angle = $\theta < 90^{\circ}$, Good Wettability
Examples: Water and Surfactant/Bituminous Coal, Pure Water/Clean Glass



c) Forces Acting at a Solid, Liquid, Gas Interface

FIGURE 5-1
CONTACT ANGLES AT LIQUID/GAS/SOLID INTERFACES

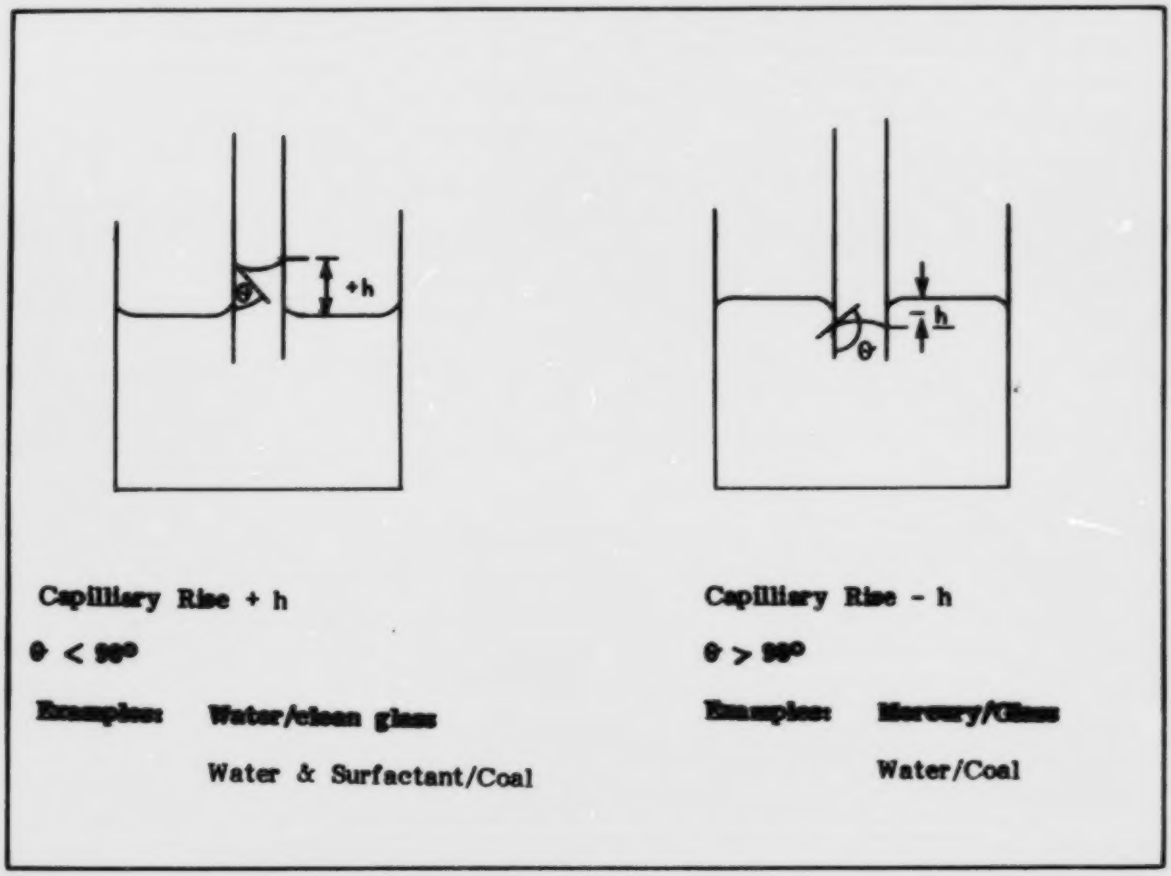
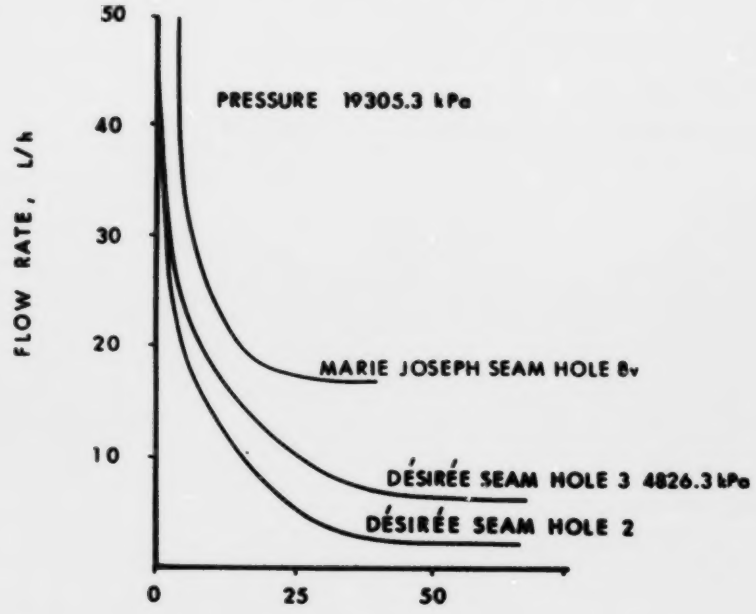


FIGURE 5-2
VARIATION IN CAPILLIARY RISE WITH DIFFERENT CONTACT ANGLES



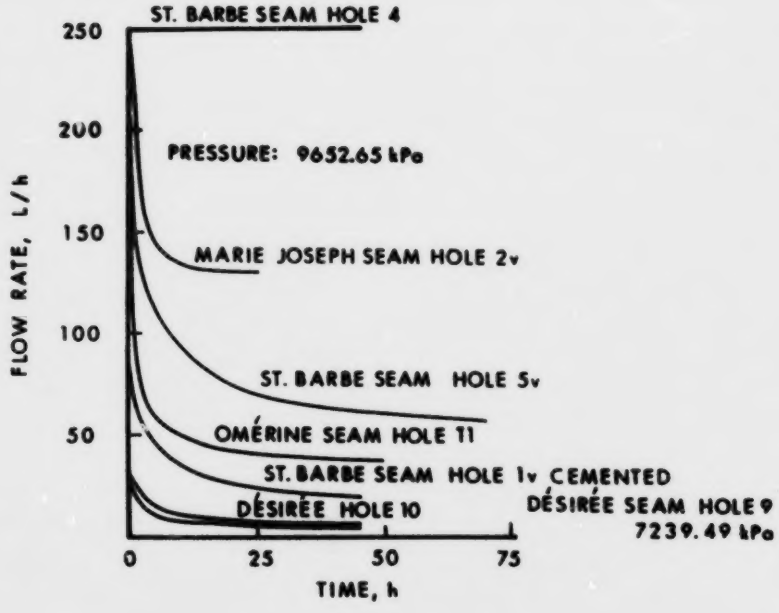


FIGURE 5-3

ISOBARIC CURVES FOR INFUSION OF COAL

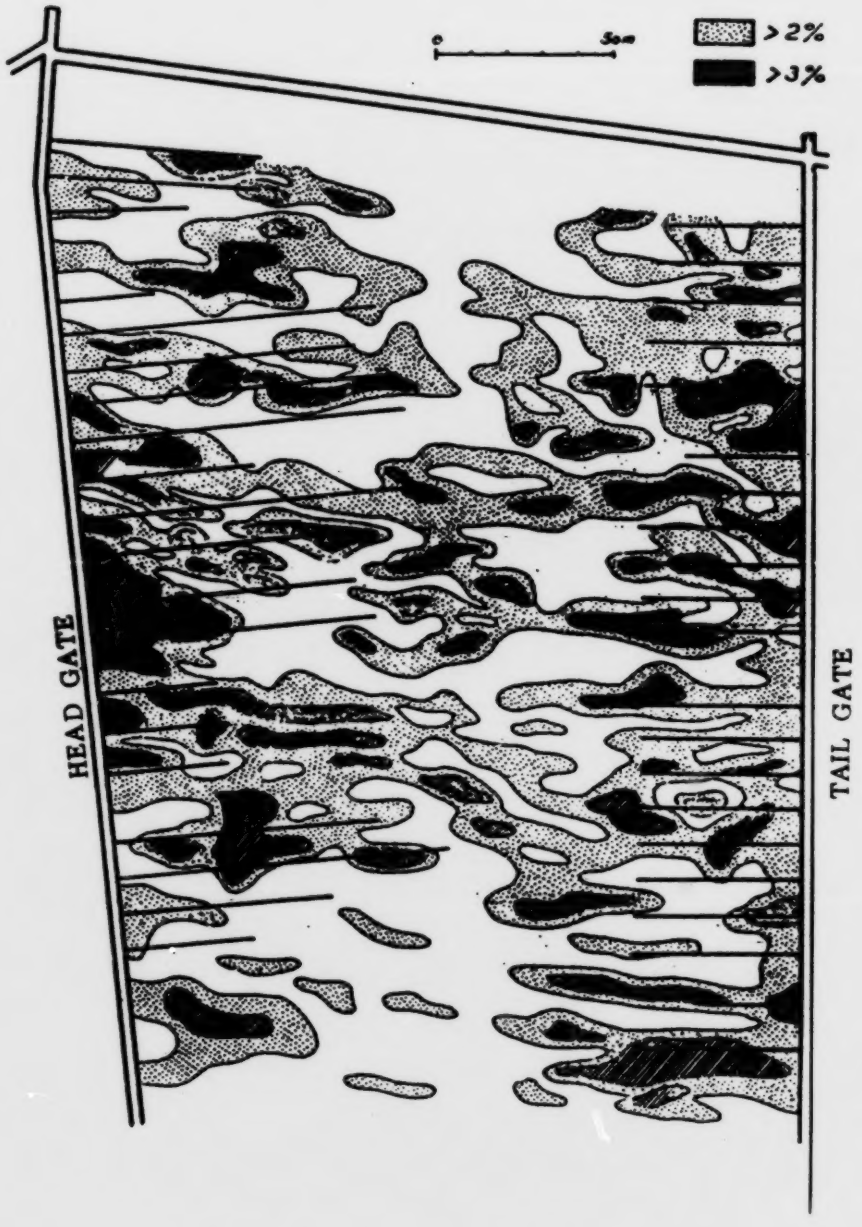
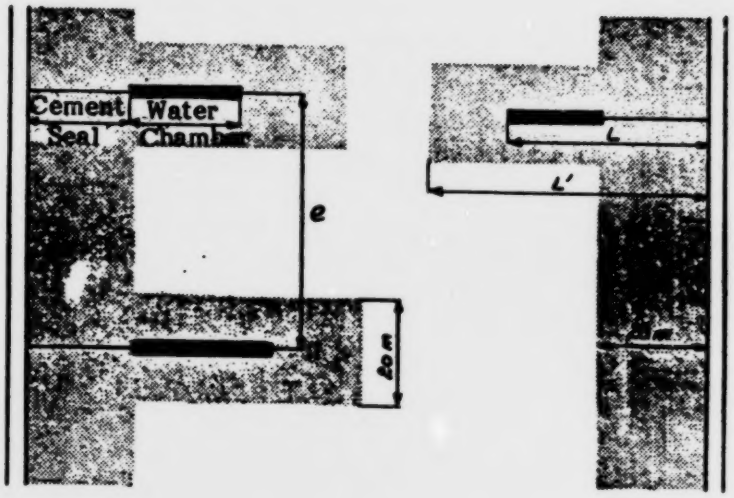


FIGURE 5-4

ISO-MOISTURE MAP OF INFUSED COAL SEAM



Areas of Significant Moisture Increase Around Infusion Boreholes.

FIGURE 5-5
AREAS OF SIGNIFICANT MOISTURE INCREASE AROUND INFUSION BOREHOLES

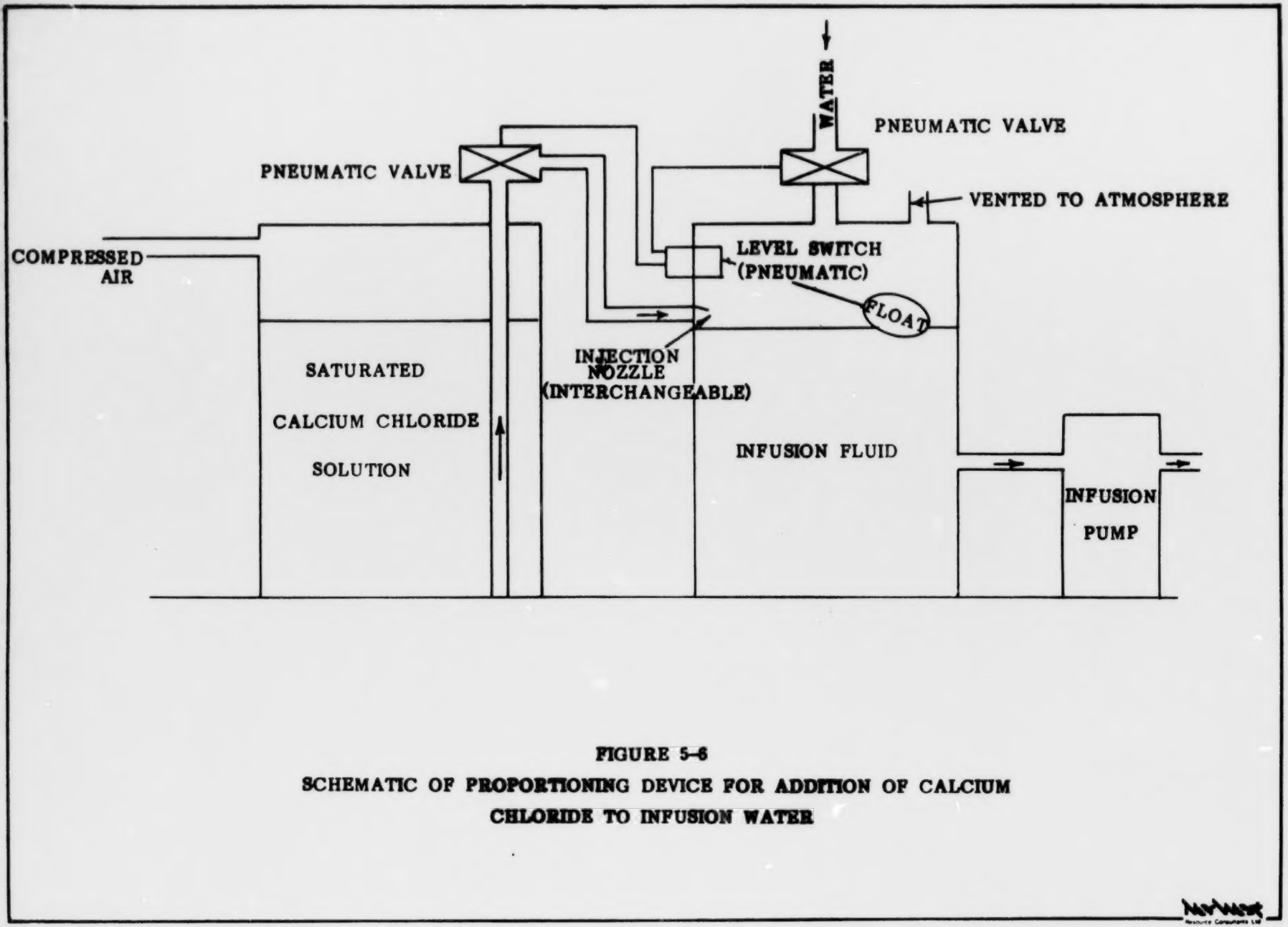


FIGURE 5-6

SCHEMATIC OF PROPORTIONING DEVICE FOR ADDITION OF CALCIUM CHLORIDE TO INFUSION WATER

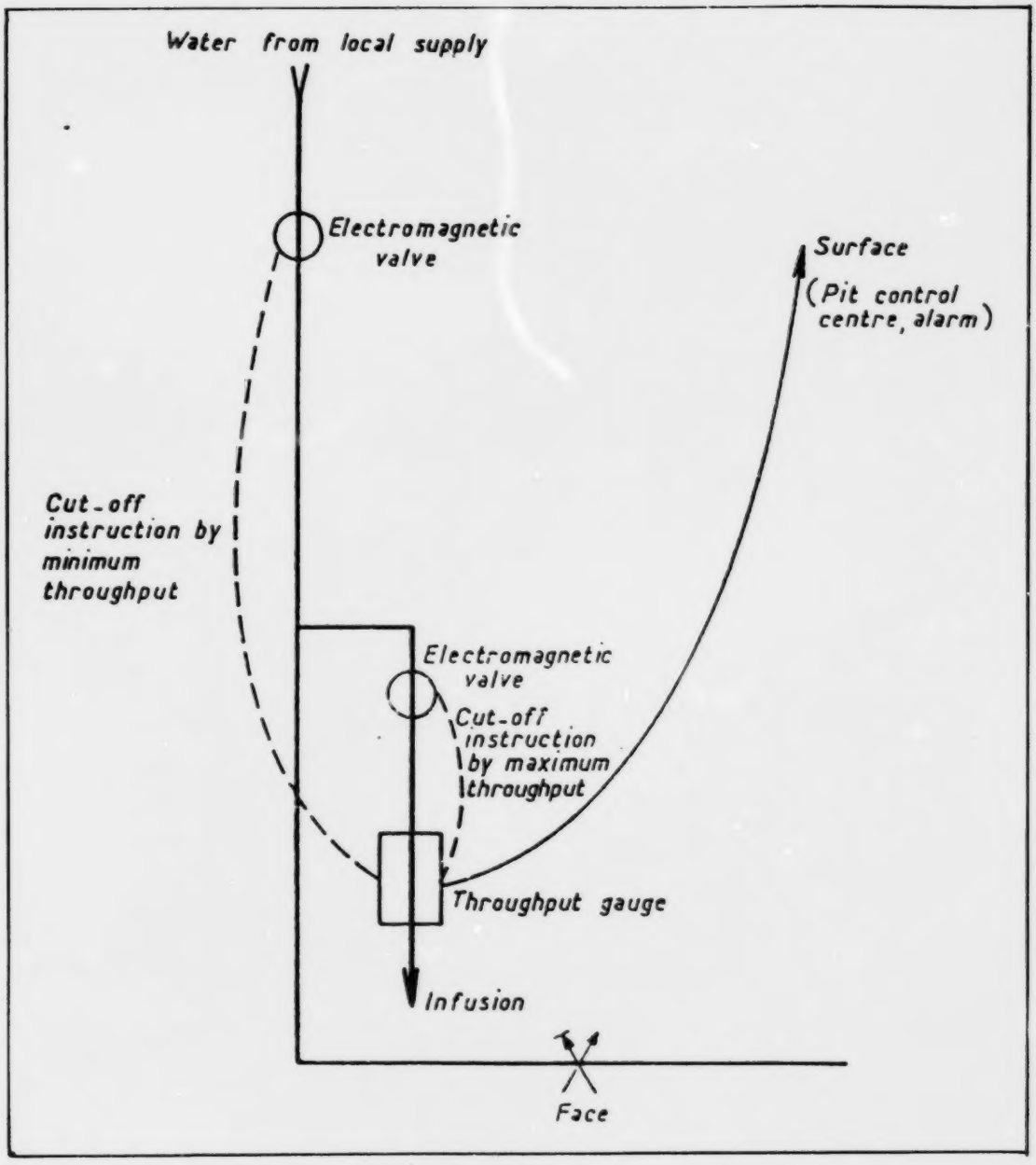
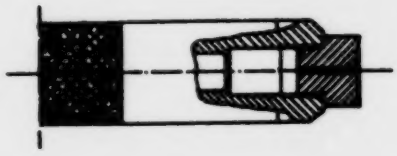
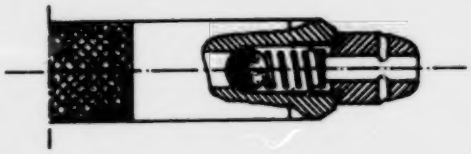


FIGURE 5-7

SCHLUMBERGER SYSTEM FOR INFUSION WATER CONTROL



ORIFICE WITH
SIMPLE JET



ORIFICE WITH NON-RETURN
BALL VALUE

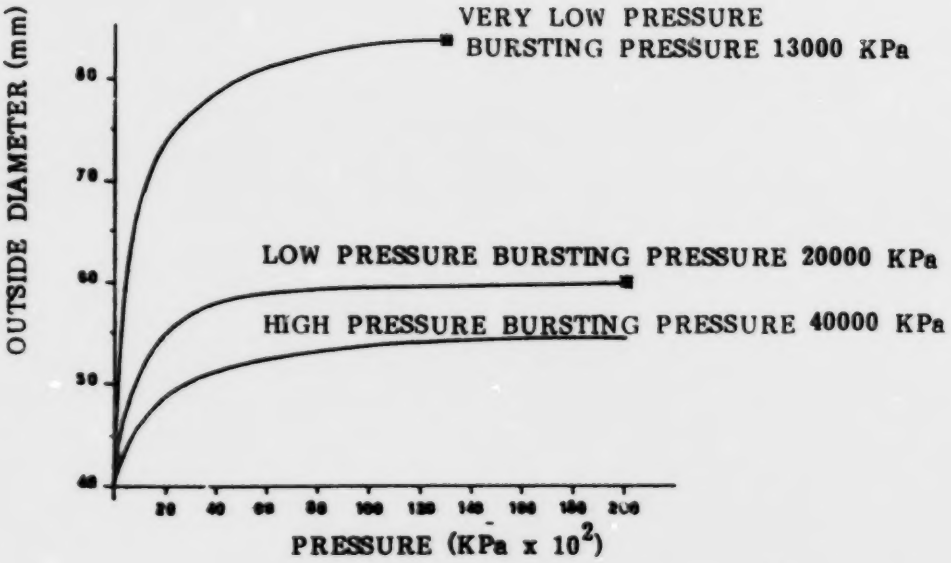
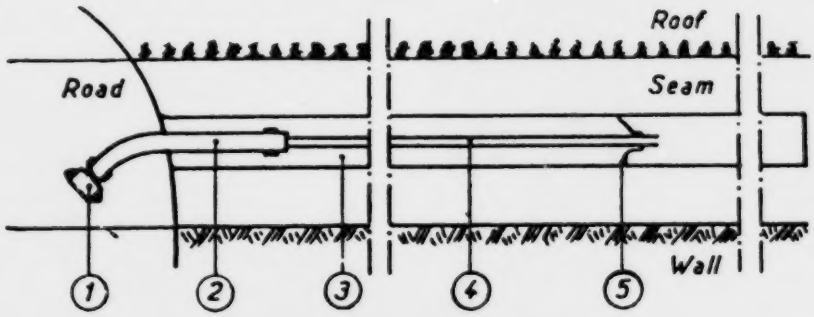

OUTSIDE DIAMETER (mm)
VERY LOW PRESSURE
BURSTING PRESSURE 13000 KPa
LOW PRESSURE BURSTING PRESSURE 20000 KPa
HIGH PRESSURE BURSTING PRESSURE 40000 KPa
PRESSURE (KPa x 10^2)

FIGURE 5-8

INFUSION PROBE FLOW CONTROL ORIFICES AND SPECIFICATIONS FOR SELF SEALING PROBES



1 - Lower joint
2 - High pressure flexible tube
3 - Cement
4 - Plastic tube
5 - Rubber cone stopper

FIGURE 5-9

TYPICAL REQUIREMENTS OF A CEMENT SEAL FOR LONG INFUSION HOLES

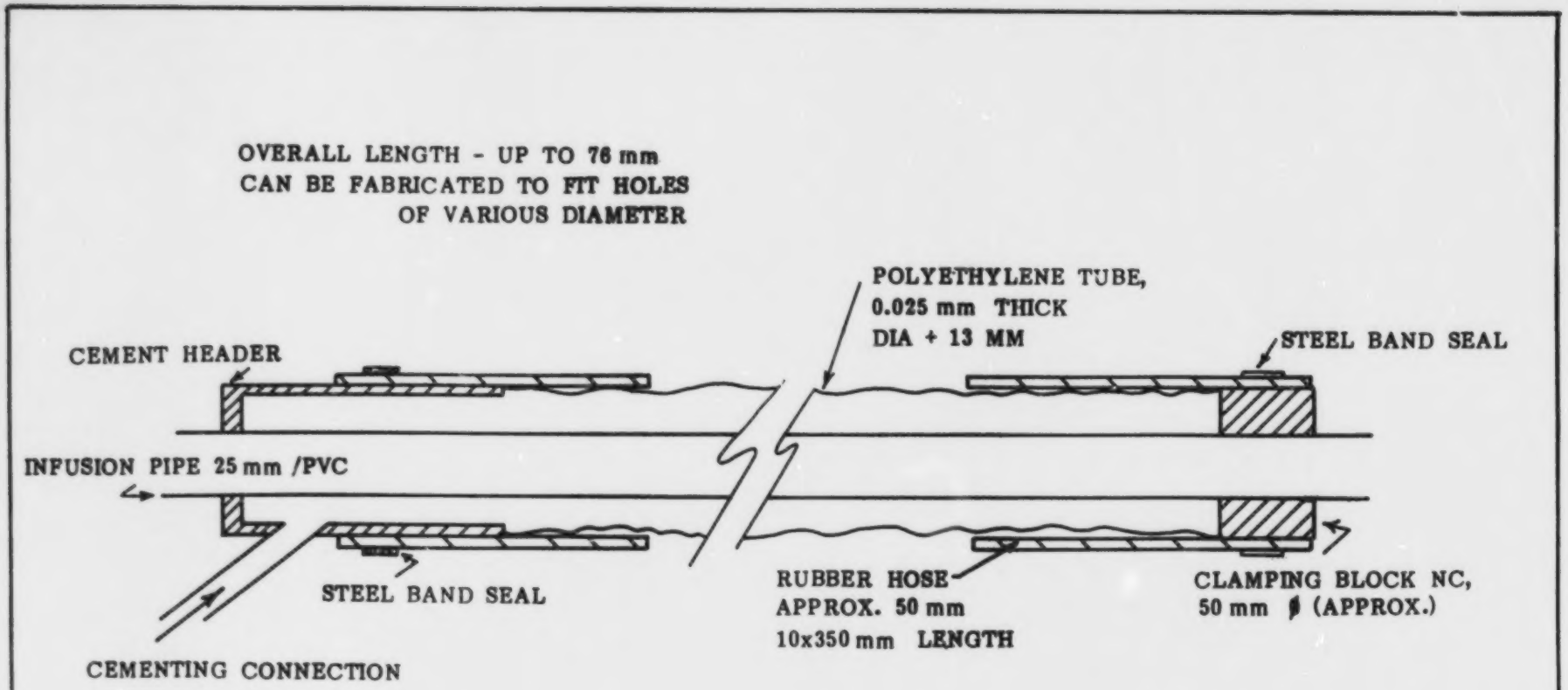


FIGURE 5-10

ELEMENTS OF THE U.S.B.M. CEMENT SEAL SYSTEM

SECTION 6

CASE STUDIES

6.1 INTRODUCTION

Water infusion applications in three collieries and the North Rhine Westphalia mining district are described as case studies in this section. The case studies were selected on the basis of similarity between operating conditions at the study sites and those existing in the Sydney coalfield. The availability of suitably detailed information regarding the results of water infusion was also an important criterion for selection.

The sources of information were primarily published reports. Discussions with German mining engineers provided additional data for the review of the practices in the North Rhine Westphalia district.

Case Study 1, the Holditch Colliery, was reported by J.W. Evans and P. Karoly at a Symposium on Environmental Engineering in Coal Mining, Harrowgate 1972; Case Study 2, Easington Colliery, was reported by J.M. Thornton at the same symposium. The third cast study was reported by J. Cervik, A, Santiano and E. Baker of the USBM. The published papers containing these reports are listed in the Bibliography.

The original work of these authors has been reformatted as necessary to allow easy comparison from case to case but as much as possible of the authors own text has been retained in an edited form.

6.2 CASE STUDY 1

Holditch Colliery

1. Background

Mine Location: Staffordshire, U.K. "Ten Feet" seam

Mining Method: Longwall advance, face length 159 m

Seam Description: Coal rank 401, inherent moisture 1.3%, Ash 4.2%, average thickness 3.73 m, consisting of 3.0 m of hard bright brittle coal at the top and 0.73 m of carbonaceous mudstone and inferior coal at the bottom. The direction of primary cleat is 95° to the face with a well pronounced secondary cleat at 5°, natural and induced fracture planes with near vertical dip parallel the secondary cleat. Full dip of the seam is 20°. The roof consists of 4.5 m of dry brittle grey mudstone overlain alternately by sandstone and siltstone 9 m thick. The floor is soft fireclay.

Mining Considerations: The face, a single unit, was 159 m in length, rib to rib, rising at 1 in 10 on the line of advance, with the face line dipping at 1 in 10 in favour of the load. Both roads were on the rib with 1.8 m of Aglite block packs on the face side. A ranging shearer extracted 2.36 to 2.44 m in the middle of the seam along the face and 1.83 m across the pack area. Both stables were eliminated and the shearer cut the floor to 0.61 m in depth across both roadheads. A quantity of 1190 m^3/min of

air was circulated in the district to keep methane within 0.6%-0.8%. Methane drainage was practised in both the intake and return roadways.

The planned performance was three strips per shift on two shifts per day, producing 270 tons per strip. The average achieved was two strips per shift. The machine, cutting at 3 m per minute, produced five tons. At the time of the trials the face was worked on one shift only for planning reasons. The plan of the panel is shown in Figure 6-1.

Special Considerations: Deep (up to 900 m), gassy coal seam in which dust suppression has long been difficult. Dust concentrations of 19 mg/m^3 were recorded prior to improvement of conventional dust suppression methods when they were reduced to around 16 mg/m^3.

2. Water Infusion Procedure

Design: Advancing face, short and medium depth infusion from the face. The layout of holes is shown in Figure 6-2.

Drilling: With the exception of the short hole full-face method, only two men were employed throughout the trials: a time study on average drilling was as follows:

Depth Drilled (m)	Preparation (min)	Drilling (min)	Total (min)	Machine Used
4.57	2	5	7	Hand-held drill
9.14	20	25	45	Victor drill

Hole Sealing: Infusion Probe (GESBO)
1, 1½ or 2½ m long. Interwoven nylon fibre sandwiched between two rubber sheaths, provides seal and anchorage by expanding under flow pressure, 40 mm outside diameter, 16 mm inside diameter with an expandable discharge orifice of 4 mm will expand to 52-53 mm in free atmosphere under a bursting pressure of 20,684 - 23,442 kPa. Connected to infusion rods or hose by means of a left-hand threaded connector, making withdrawal possible if the gun gets fast.

Pressure and Volume: The pressures and volumes used in the infusion trials are shown in Table 6.1. A wide range of pressures were tested in holes of different lengths and over varying infusion times.

Pumps: Single-stage, 3 cylinder ramp pump. Driven by a 65 hp standard AFC motor. Deliver of 91 l/min against pressures of up to 41,368 kPa, fitted with an integral tank of 68 l capacity with suction direct from the mains. Pressure gauge and relief valve are integrally fitted. The trial used a T50 Gullick pump, delivered 68 - 340 l/min at 24,820 kPa.

Other Equipment:

Instruments

Totalizing flow meter and pressure gauge are coupled into the branch line of hole being infused. With deep hole trials no flow meter was used, quantities being calculated on a time basis.

Main Hosing

16 mm internal diameter, working pressure in excess of 34,473 kPa in 15 m lengths coupled together by connectors gripped into the hose end. Along the face, connections are made by means of "T" pieces providing points of supply to infuse individual holes. The "T" pieces are fitted with two lever type valves, isolating main or branch hoses as required.

Infusion Hose

16 mm diameter, 1 or 2 m long, similar in construction to the main hose. Fitted with relief valve. Used to infuse short holes only.

Infusion Rods

High quality, non-corrosive steel, 1½ m long, hexagonal ends and screwed connections, 28 mm outside diameter, 16 mm inside diameter.

3. Results of Water Infusion

Effect on Dust:

Airborne dust samples, using the gravimetric sampler type 113A, were taken simultaneously in the intake and return during production on the day shift.

The coal appeared to have been softened and dust on fracture and cleat planes dampened, although not uniformly. Dust causing physical discomfort was reduced and visibility during shearing was improved.

Reduction in airborne dust concentration attributable to the infusion trials was 0.5 mg/m^3 in the intake and 1.75 mg/m^3 in the total face-make, compared with the average concentration during the eight months preceeding the trials.

The results of the trial are shown in Table 6.1 where dust concentration is tabulated with infusion details for comparison.

Effect on Methane, Humidity and Temperature:

Methane monitored continuously in the return airway revealed no change in emission rate.

Humidity tests carried out on three successive days in the district return gave mean values of 82%, 84% and 86%, compared with 85%, 80% and 85% from monthly measurements. The ambient temperature was 25°C.

Strata Control:

Roof and floor penetration tests were carried out by strata control engineers at three points on the face. Roof penetration force before and after the trials was 11,376 kPa and 11,583 kPa, respectively; floor penetration before and after was 7,122 kPa. Infusion did not result in a weakening of the roof and floor.

Although on occasions as much as 20,000 l of water was infused in 21 equally spaced short holes (5 m) in a single shift, no deterioration of roof on face or in roadheads occurred.

4. Discussion

The German GESBO infusion equipment is simple and easiiy handled on the coal face. The seals were not fully effective with every hole, but with short holes the rate of flow-back indicated the leakage was via breaks rather than past the seal. Dangerous ejection occurred only once resulting in breakage of supply connections, but the tendency to eject was apparent in each case when infusion was terminated with pressures around 13,800 kPa.

Analysis of five samples of minus 25 mm coal showed a mean moisture content of 6.6% when shearing and 8.3% when flitting. A valid comparison was not possible since pre-infusion tests were not carried out, but ROM smalls sampled on the surface prior to the trials showed higher values by 2%.

In short hole (daily advance +0.5 m) infusion, the water spreads mainly into open cleat planes and pressure partings and penetration into finer breaks will therefore be irregular. Infusion pressures are comparatively low and vary widely during infusion. About 2% of water is added as calculated on daily extraction. It is a simple process, technically fully developed and widely used in Germany. It main disadvantage is that water may break through to the free face via open breaks in coal or roof before the required quantity can be infused.

With medium deep and deep holes much higher infusion pressure is needed, which may vary or remain constant during infusion. Distribution of water is more regular and percolation into finer fissures takes place. The system requires high pressure equipment, good sealing and equipment to drill holes

accurately to 20 m depth. Quantities of water infused are of the order of 1-1.5% of extracted coal.

Medium deep holes were initially practised, the depth of hole being equal to more than 5 days face advance; this was estimated at approximately 10 m on one production shift per day. The holes were dipped for the first 3 weeks, on the understanding that water entering the roof coal might result in bad roof conditions. Such a problem did not materialize, however, even though on numerous occasions water dripped from the exposed roof when short (less than 5 m) holes were infused, and accordingly the holes over the last three weeks were bored to incline upwards, reaching extraction height at the back end.

With the face producing on one shift per day the pressure breaks and cleat planes were well developed, with easy escape for water. To counter this, holes were bored to 10.6 m in depth for one week after which it was agreed to double shift the face. No escape of water to the free face was then observed until the short hole method was applied. The escape of water was particularly evident near the face end on the lines of the secondary cleat - the main gate end would be "weeping" after infusing 880 l in a 4.5 m hole some 10 m away.

The short hole method was practised during the last two weeks of the trials - the full face method in the first week, and the half-face method in the second week. The quantities per hole in the half-face method were nearly double those of the full-face method.

The technique of drilling and infusion was quickly acquired by the colliery team of two men and no undue difficulties were experienced. At the end of the trials this team was fully competent to record details. Equipment lost comprised two infusion guns and one drill rod, and one gun and two infusion rods were damaged.

6.3 CASE STUDY 2

Easington Colliery

1. Background

Mine Location: South Durham, U.K.

Mining Method: Longwall Retreat

Seam Description: The "E" Seam consists of 1.65 m of coal at the bottom, a thin mudstone band and a further 0.23 m of coal. The roof in the area of the trials was shale, compressive strength 5,160 - 5,860 kPa and the floor was seggar, compressive strength 3,100 kPa.

Mining Considerations: The face selected was already on production. It was 91.4 m long and 2 m high, and worked on the retreat system using an AB200 (150 kW) Bi-Di Shearer fitted with external water sprays for dust suppression purposes (drum size: 1.68 m x 69 cm).

Special Considerations: At Easington Colliery, in 1960, when airborne dust problems were encountered with Joy Continuous Miners, experiments were carried out in the "E" Seam in an attempt to water infuse the coal ahdead of the machine. The aim was to control the infusion so that the heading only was infused.

Using various hole lengths up to 30.5 m and water pressures from 2,068 - 20,680 kPa, it was found impossible to control the waterspread in advance

of the heading to the desired 4.9 m width and 30.5 m depth.

Some strata control problems were introduced by the water affecting adjacent strata and as a result, water infusion was dropped as a dust suppression technique in this seam.

In Durham, the "E" Seam which is naturally dry and dusty has been, over the years, the subject of many experiments on water infusion techniques along the faces with water pressures of about 3,450 kPa and deep hole infusion along the faces using expensive water infusion guns at pressures up to 20,680 kPa.

Early trials usually resulted in the water infusion affecting either the roof or floor or both to the detriment of strata control. Until 1970 water infusion in this seam was not acceptable as a useful routine dust suppression technique.

2. Water Infusion Procedure

Design: The technique which was applied in the trials was similar to that used in some of the coal mines in Northern France, modified to suit British conditions. The main difference was that a simpler water flow system was used in Durham.

Drilling: From either or both gate roads, using standard drilling equipment and 43 mm bits, holes were drilled parallel at the seam, starting at a distance

of about 2-3 weeks face advance from the face line. Subsequent holes were drilled at 22.8 m intervals down the road, later the interval was extended to 37.6 m and 45.7 m. Figure 6-3 shows the layout of the holes.

The first eight holes were drilled to 15.2 m, the ninth and later holes were drilled to to 30.5 m.

Hole Sealing:

A 1.3 cm plastic pipe (B.S. 1972 - Standard Gauge - ½in Polythene) was introduced into the hole to a position about 0.3 - 0.6 m back from the far end of the hole. The end of the plastic tube extended into the gate road by about 1 m. A reuseable female coupling was attached to this outer end.

To eliminate the possibility of the infusion hose being choked by cement travelling too far into the borehole, the infusion hoses were fitted with fluted plastic skirts approximately 1 m from the inner end of the hose. When the cement is injected it comes aginst the fluted skirt which opens out and prevents further travel of the cement.

A second 1.3 cm plastic pipe was slipped into the hole alongside the first one and stopped at about 3 m from the far end. The purpose of this pipe was for the introduction of the sealing medium into the hole to lock and seal the infusion tube into position.

Through this second pipe, a creamy mix of cement and water was gently blown from a cylinder using a compressed air supply. As the cement passed down the tube into the hole, the cementing tube was gradually withdrawn from the hole, leaving a long plug of wet cement. This sealed the first pipe into the hole without obstructing the inner end of the pipe. On later faces, the cement mix was pumped into the holes using a Mono D3 or D4 pump which had to be cleaned thoroughly and immediately after use.

The cement was allowed 48 hours to cure and the hole was connected via the 1.3 cm reuseable coupling and the water flow control unit to the mains supply. Figure 6-4 shows the water flow control unit and coupling system.

Pressure & Volume:

Low pressure deep hole infusion was controlled at 689 - 1,034 kPa and 2.25 l/min, aiming for ½% total addition of water to the coal. This was decided on the basis of experience of water infusion effects in this seam gained from previous trials. The main water supply was reduced in presure using a standard pressure reducing valve.

The target of ½% total water addition dictated that each hole should receive approximately 22,730 l of water calculated on the total face volume and assuming even spread of water in all directions in the seam.

Pumps: No pumps were required for this low pressure infusion trial, the main water supply pressure was reduced to the required level.

Other Equipment: The instrumentation and connection system used in the trials became a standard in the coalfield and was widely used.

3. Results of Water Infusion

Effect on Dust: Pre-treatment of the faces by water infusion has always been recognized as an effective dust suppression measure. In fact, the least dusty conditions in Northumberland and Durham exist where the inherent moisture of the coal is highest. This could be considered as natural water infusion.

The mean dust concentration before low pressure deep hole water diffusion was applied was 7.85 mg/m^3 which was borderline approved. The mean dust concentration after the application of low pressure deep hole infusion was 3.7 mg/m^2. Whilst no measurements were made, it seemed that the larger sized nuisance dust, which affects comfort and vision, was also considerably reduced. Results of the trials are summarized in Table 6.2.

An all round improvement in environmental conditions had been achieved by the addition of ½% water to the coal in situ which normally contained 3% to 4% total moisture. No changes were made in the machine spraying systems.

Effect on Methane: No measurements of methane levels were made in conjunction with the water infusion trials. Because the infusion system was subsequently applied with success in many locations, it may be assumed that methane release was not adversely affected.

Strata Control: No adverse effects on either the roof or the floor were reported after the trails.

On the face and in both roadways it was possible to see water sweating out of the coal on occasions. The more usual effect of the presence of water was that the coal showed distressing effects and became easier to work. This method of infusion was subsequently adopted on 12 other faces in the area.

4. Discussion

One of the main advantages of the system is that blocks of coal can be treated before the face actually starts working, and treatment can be completed long before the face is finished. Usually an attempt is made to infuse holes at a position at least 3 weeks ahead of the face line. This method of water infusion is carried out from roadways on either side of the face and consequently is well away from the production activities.

Eventually, the stage was reached when more than one hole was being infused at the same time. However, it was necessary to use a standard flow control unit on each hole for correct metering purposes.

It would appear that in this seam the formula for correct water infusion is based on controlled low pressure supply at 689 - 1,034 kPa and controlled

rates of water flow at 2.25 l/min, which appears to avoid seam "flooding" and consequent movement of water to roof and floor. A time factor of not less than 3 weeks is required to permit full travel of the water throughout the coal.

The ability and ease with which water can be infused into coal seams would appear to be influenced by the tightness of the coal. De-stressed coal is fairly easy to infuse and the flow rates, pressure, etc., seem to be very variable over the same block of coal. Virgin coal in the same blocks appears to have reasonably constant water infusion flow rates and pressures. However, these conditions usually vary from face to face and seam to seam in the same colliery.

6.4 CASE STUDY 3

Sunnyside No. 1 Mine

1. Background

Mine Location:	Sunnyside, Utah
Mining Method:	Longwall reatreat with double entries
Seam Description:	The lower Sunnyside coalbed is mined over a thickness of 2.1 m in the area of the trials. Face cleat is 90^{o} to the face. The free water content in the fracture system was 7.5 l/m^3 of coal. The seam is typically 3 m thick with a predominantly sandstone floor and a competent shale roof. The coal is hard, high volatile bituminous and is mined as a metallurgical coal.

Mining Considerations: Panels are developed 168 m wide with double entries at each end. A double drum ranging shearer is employed on retreat mining.

2. Water Infusion Procedure

Design: Infusion from a single hole drilled from the gate was studied to evaluate the effect of long term, low pressure infusion. Figure 6-5 shows the layout of the mining block and hole locations.

Infusion: A 7.6 cm diameter hole was drilled to a depth of 91 m using standard drilling equipment. A Pajari borehole surveying tool was used to check the hole trajectory.

Hole Sealing: The hole was sealed with a USBM packer to 71 m, leaving 20 m of open hole for infusion of water into the coalbed.

Pressure & Volume: During the day shift, water was forced into the coalbed with a pump at a rate of 102 l/min at 4,130 kPa. On the other two shifts, the mine water supply line was connected to the hole. Water flow rates and pressure were 49 l/min and 2,170 kPa, respectively.

The calculated quantity of water required to saturate the panel was 464,000 l based on a circular infusion zone and 1.0 pct fracture porosity. The actual quantity of water infused over a 10-day period was 787,300 l. Water seeps were observed along both ribs of the panel up to

168 m on both sides of the water infusion hole. Water migrated faster by a factor of about 2 along the axis of the longwall (approximate face cleat direction) than towards the ribs of the panel, indicating an elliptical infused zone. No surfactant was used in the infused water.

Pumps: The pump used was capable of delivering 102 l/min at a pressure of 4130 kPa. The exact type of equipment used was not specified.

Other Equipment: The USBM packer is described in Section 5 of this study, its design is the subject of a U.S. patent.

Water pressure and volume meters were standard equipment.

3. Results of Water Infusion

Effect on Dust: Four dust sampling surveys were conducted to determine the effects of water infusion on dust generation during mining. Each sampling period was 6 to 8 days. The first survey was conducted before water was infused into the panel, to establish a base dust level for comparison with dust levels in the infused zone. The following surveys were conducted in the infused zone: (1) when the panel face was 122 m to the right of the infused hole (test 1), (2) when the face passed through the vicinity of the infusion hole (test 2), and (3) when the face was about 183 m to the left of the infusion hole (test 3) (Figure 6-5).

Dust measurements were made with MSA Monitor Model G personal dust samplers. A set of four instruments was hung from a shield directly over the chain conveyor and approximately 30 m upstream from the tailgate entry. Intake air was also monitored with a set of four instruments, and those dust levels were subtracted from the dust levels at at the tailgate station. Because the velocity of the ventilating air varied from 0.5 to 2.0 m/s and the tonnage of mined coal varied from 572 to 3,574 t between sampling shifts, all dust measurements were divided by tonnage of coal mined during the sampling shift and then corrected to an air velocity of 1.5 m/s. Data for the air velocity correction were generated by the Mine Safety and Health Administration (MSHA) from a 1978 survey of all longwall sections for compliance with respirable dust standards. This survey showed that dust levels during mining tended to be less on longwalls where air velocities at the tail end of the longwall were higher. However, where air velocities were above 2.5 m/s, dust levels increase because of dust entrainment.

The effects of water infusion on respirable dust generation during longwall mining are summarized in Table 6.3. Line 1 in the table shows the average Mining Research Establishment (MRE) dust concentration for the noninfused zone and the three surveys in the infused zone. The measured dust levels are affected by variations in air velocity near the tail end of the longwall (line 2) and by coal production (line 3), which increased

by a factor of about 3 between the first and last survey. To correct for variations in air velocity and coal production, dust concentration were normalized to an average air velocity of 1.5 m/s and then divided by tonnage mined during the sampling shift. Line 4 shows the corrected dust concentrations. In noninfused coal, dust concentrations average 0.0050 $mg/m^3\ t^{-1}$ of mined coal, compared with 0.0018 to 0.0026 $mg/m^3\ t^{-1}$ in the infused zone. Thus, water infusion reduced the generation of respirable dust during mining by 47 to 64 pct (line 5). Average dust reduction was 58 pct.

Because of day-to-day variations in dust levels and variations between dust sampling periods, the dust data were analyzed statistically using the t test to determine if the differences between the average dust levels in noninfused and infused coal (line 4) are significant.

The average dust level of each test in infused coal was compared to the average dust level in noninfused coal. The calculated t values were in each case greater than the theoretical t value at the 1 pct probability level. Thus, the probability that no differences exist between dust levels in noninfused and infused coal is only 1 pct or less. Stated in another way, the probability is 99 pct or greater than water infusion suppresses dust generation during mining.

The average quantity of water used by the spray system of the shearer each shift during the study is shown in line 6. No changes were made to the shearer's spray system during the study. Line 7 showns that the water consumed by the spray system gradually decreased from 65.8 l/m^3 and of mined coal during the first survey to 29.4 l/m^3 during the last survey. One would expect dust concentration to increase, but the three surveys in the infused zone (line 4) show that dust concentrations generally decreased. These data suggest that increasing the water consumption of the spray system above 29.4 l/m^3 of mined coal in the Lower Sunnyside Coalbed would not be effective in suppressing respirable dust during mining.

Effect on Methane: No effects on methane release were reported.

Strata Control: No adverse effects on strata control were reported.

TABLE 6.3

EFFECTS OF INFUSION ON DUST GENERATION

Effect		Noninfused Zone	Infused Zone Test 1	Test 2	Test 3
Average MRE conc.	mg/m^3	5.2	2.3	2.4	4.8
Average air velocity	ft/min	190	340	350	240
Production	tons/shift	830	1,010	1,420	2,680
Corrected MRE conc, per ton	mg/m^3	0.0045	0.0024	0.0017	0.0016
Dust reduction	pct	NA	47	62	64
Average water use	gal	10,200	9,500	10,500	14,700
Average water use	gal/ton	12.3	9.4	7.4	5.5

NA = Not applicable

6.5 RECENT INFUSION PRACTICE AT NORTH RHINE WESTPHALIA COALFIELDS

1. Background

Mine Location: North Rhine Westphalia Coalfields

Mining Method: High speed advance and retreat longwalls, some in steep seams.

Seam Description: Several seams are frequently present and ground stresses from previous or adjacent workings often impact on the permeability of the coal and hence its infusibility. Seam thickness is commonly around 2 m although large and smaller seams are

worked. The coal is either soft enough or fractured sufficiently to allow the extensive use of ploughs.

Mining Conditions: High speed, high productivity longwall mining is common in this area. Shields are the most used form of face support, coal is often cut with ploughs although shearers are also used. Mines are commonly deep, large and complex having several working horizons. Ventilation requirements are severe due to depth, methane and rock temperatures. The existence of multiple seams and frequency of steep seams has encouraged the use of remote infusion ahead of current workings by drilling from places above or below the seam.

Special Considerations: The West German coal industry is protected against low priced imports by Government imposed trade barriers. The industry has some of the highest operating costs in the world but is maintained for strategic and social reasons despite the availability of much cheaper coal in the world market place. These conditions, coupled with a strong desire to reduce the hazards of underground mining have encouraged the use of sophisticated and expensive systems for the mining of difficult coal in deep mines. Infusion with water is very common in Germany, in 1983, 92% of coalfaces in the North Rhine Westphalia region were regularly infused.

2. Water Infusion Procedure

Design: Short hole from the face, long hole from the roads and remote infusion are used extensively.

Drilling: Standard short and long hole drills are employed. Recent advances in drilling techniques include: the development of a hydraulic turbo-drill which uses high pressure water jets to cut the coal; drilling with large diameter (up to 76 mm) augers in highly fractured and stressed areas: use of face conveyor to transport drills at the face.

Hole Sealing: Both self inflating hydraulic packers and cement seals are common. The equipment in use is essentially unchanged over the last decade.

Pressure & Volume: In the wide range of applications in the coalfield a correspondingly wide range of infusion pressures are used. The typical range of presures is from reduced mine supply pressure as low as 2000 kPa to occasionally as high as 50,000 kPa.

Infusion is commonly controlled by adjusting the pressure to provide flow rates in the order of 10 l/min for infusion from the face and less for infusion from the roads or remote infusion. Use of high pressures to achieve flows of 80 l/min at the face have been reported where infsuion times must be kept short.

The quantity of water infused for dust suppression varies but a target quantity of 10 l/m^3 of coal is common.

Pumps:

Positive displacement piston pumps of the type commonly in use for hydraulic service are employed as infusion pumps. The firm of Hauinco in Essen manufacturers a range of pumps with motors from 10 - 90 kW, operating pressures up to 60,000 kPa and outputs up to 190 l/min. The smaller sizes of this range of pumps are in use as infusion pumps in West Germany, Belgium, France and the U.K.

Other Equipment:

Flow and pressure monitoring devices, including remote monitoring systems have been developed in West Germany. These systems have been used to monitor infusion from the roads where infusion is continuous over long periods. Small in-line flow meters capable of handling high pressures are available for monitoring infusion at the face.

Several devices have been developed for the addition of wetting agents and salts to the infusion water. These include tanks for controlled, automatic addition of salt solutions, chambers for the dissolution of salts from solid cartridges and small displacement metering pumps for the addition of surfactant chemicals.

3. Results of Water Infusion

The widespread use of water infusion in West German mines and the regulatory requirement for its use tends to inhibit comparison of before and after dust conditions.

German experience shows that the respirable dust made can be reduced by up to 50% by infusion. This reduction now seems to be a firmly accepted fact and recent work (since 1979) does not appear to be concerned with proving the relationships between dust inhibition and infusion. Current research is aimed at faster drilling of infusion holes, more efficient borehole sealing, development of flow pressure, measurement devices, control systems and methods of accurate dispensing of additives.

Effect on Methane:

The available German research information makes no mention of the effect of infusion on methane release. This may be more a question of reporting in separate categories rather than an actual absence of observations. West German mines have an average methane release of 8.5 m^3/min or 18.2 m^3 per tonne of coal.

Strata Control:

Early reports of German water infusion (Schlick 1970) stressed the need to avoid drilling into the roof or floor and cautioned against the potential for damage to strata. It is believed that some of the coalfaces not infused in 1983 may have had

potentially weak strata conditions which would have been adversely affected by water infusion.

4. Discussion

The multi-seam nature of many German coal deposits has encouraged the use of remote or hyper-tele-infusion. This method, together with infusion from the face accounts for approximately 75% of longwall infusion installations, (about 25% of the faces use retreat mining).

The common use of pneumatic de-dusters in coal preparation plants requires that moisture the content of raw coal be kept reasonably low (less than 6%). This discourages the excessive use of water spraying and tends to encourage water infsuion which generally provides better dust inhibition with lower quantities of added moisture.

Relatively high methane emission rates and high formation temperatures require large volumes of ventilation air to maintain safe working conditions. The relatively high air velocity at faces can cause dusting problems. Water infusion reduces the amount of fine dust entrained into the air stream or allows higher velocities to be achieved with no increase in dust concentration.

EASINGTON COLLIERY—E.71
RETREAT FACE LOW PRESSURE DEEP HOLE INFUSION

Water Addition
Total addition: ½% at 150 lb/in²–200 lb/in² static
Rate of flow: ¼ gal/min
Holes 25 yd apart at 5p ft depth (holes 1 to 8) and 40 yd apart at 100 ft depth (hole 9 onwards)

Dust Measurements and Production Details

Date	*Mass of Dust (mg/m³)*	*Coal Production (6 ft 6in seam)*		*Sample Time (min)*
PRIOR TO INFUSION		*	*	
14.5.70	8·1	Sheared 400	Plough 300	280
2.6.70	7·6	Sheared 285	Plough 285	300
AFTER INFUSION				
29.6.70	2·3	Sheared 300	Plough 250	304
30.6.70	1·9	Sheared 400	Plough 400	304
1.7.70	1·7	Sheared 150	Plough 150	300
2.7.70	3·7	Sheared 450	Plough 450	308
7.7.70	2·9	Sheared 300	Plough 200	301
8.7.70	4·2	Sheared 300	Plough 350	280
9.7.70	4·8	Sheared 350	Plough 400	288
10.7.70	4·5	Sheared 400	Plough 300	280
13.7.70	5·4	Sheared 450	Plough 400	280
14.7.70	4.0	Sheared 300	Plough 300	280
15.7.70	4·4	Sheared 300	Plough 200	280
16.7.70	3·2	Sheared 500	Plough 400	280
21.7.70	3·5	Sheared 250	Plough 150	274
22.7.70	4·7	Sheared 400	Plough 300	268
29.7.70	4·3	Sheared 400	Plough 400	282
FACE INTAKE SAMPLES				
7.7.70	1·1	Full coaling		305
21.7.70	1·3	Full coaling		290

* Surveyor's measurement = to yd approx

Table 6.1

INFUSION DETAILS AND RESULTS—HOLDITCH

Date	No. of Holes Infused	Average Pressure psi	Average Quantity per hole (gal)	Average Time per hole (min)	Total Quantity (gal)	Coal Extracted (tons)	Dust Concentration Int.	Ret.	Face Make
Hole 30 ft deep, 45 ft apart, 5 ft from floor, dipping 6°. Single shift shearing.									
21.4.71	4	1610	495	26	1980	—	6·4	15·4	9
22.4.71	6	1850	920	53	5520	876	6·5	16·6	10·1
23.4.71	—	—	—	—	—	583	4·9	10·9	6
Holes 35 ft deep, 60 ft apart, 5 ft from floor dipping 6°. Single shift shearing.									
26.471	3	2050	990	65	2970	583	4·5	15·6	11·1
27.4.71	2	1330	585	27	1170	583	5·3	14·2	8·9
28.4.71	4	1680	795	54	3180	292	5·4	10·1	4·7
29.4.71	—	—	—	—	—	583	4·2	12·0	7·8
30.4.71	1	1100	880	30	880	583	—	11·0	—
Holes 30 ft deep, 60 ft apart, 5 ft from floor, dipping 6°. 2 shift shearing.									
3.5.71	1	2740	3300	170	3300	583	5·7	6·8	1·1
4.5.71	3	2590	1450	75	4400	583	6·0	12·0	6·0
5.5.71	3	1230	1320	56	3960	1020	5·5	15·2	9·7
6.5.71	3	1540	1063	46	3190	1020	4·5	15·6	11·1
7.5.71	2	1500	1210	75	2420	730	7·0	11·5	4·5
Holes 30 ft deep, 50 ft apart, 5 ft from floor, rising 6°. 2 shift shearing.									
10.5.71	3	2290	1100	53	3300	1020	3·8	14·1	10·3
11.5.71	3	2280	1100	56	3460	885	3·7	13·7	10·0
12.5.71	3	1920	1100	48	3300	885	4·3	9·8	5·5
13.5.71	3	2420	1100	50	3300	1020	3·3	15·0	11·7
14.5.71	3	2000	1100	50	3300	885	4·1	10·6	6·5
Holes 15 ft deep, 25 ft apart, full-face method. 2 shift shearing.									
17.5.71	20	500	162	9	3234	1216	4·7	14·7	10·0
18.5.71	20	480	167	7	3344	1070	3·8	11·8	8·0
19.5.71	19	600	164	9	3124	912	3·1	11·3	8·2
20.5.71	21	540	210	8·7	4400	1337	3·3	12·5	9·2
21.5.71	20	700	204	8·9	4092	1020	3·5	8·9	5·4
Holes 15 ft deep, 25 ft apart, half-face method. 1 shift shearing.									
24.5.71	11	700	362	15	3982	802	4·6	7·3	2·7
25.5.71	10	400	425	13·7	4246	535	4·2	9·7	5·5
26.5.71	10	520	402	18·8	4026	802	6·3	13·4	7·1
27.5.71	11	600	425	15·5	4246	802	4·9	12·9	8·0
28.5.71	—	—	—	—	—	267	5·9	13·5	7·6
						Average:	4·79	12·41	7·62

Period	No. of Samples	Average activity Shears	Flits	Average concentration mg/m³ Intake	Return	Face Make
July 1970 to April, 1971.	29	1·6	1·83	5·29	14·66	9·37
6 weeks' Trials	27	1·33	1·22	4·79	12·41	7·62

Table 6.2

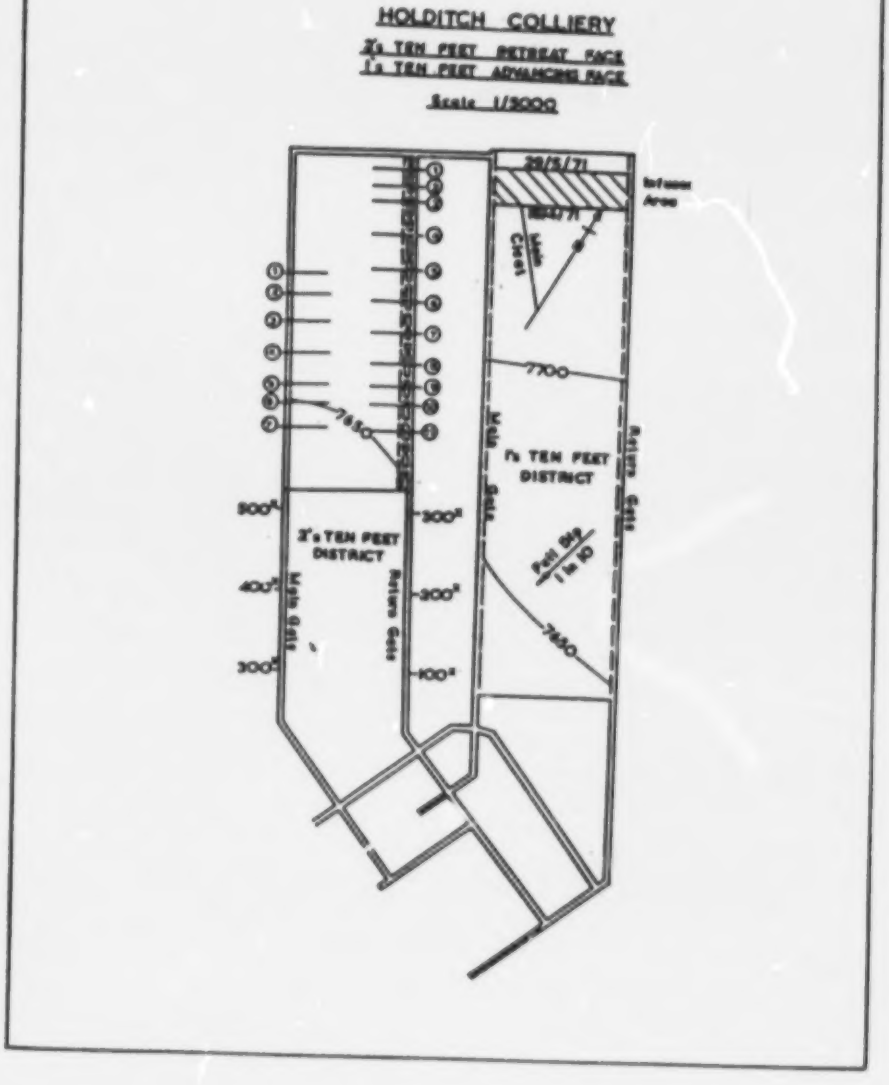


FIGURE 6-1
HOLDITCH COLLIERY, PLAN OF WORKINGS & LOCATION OF INFUSION TEST AREA

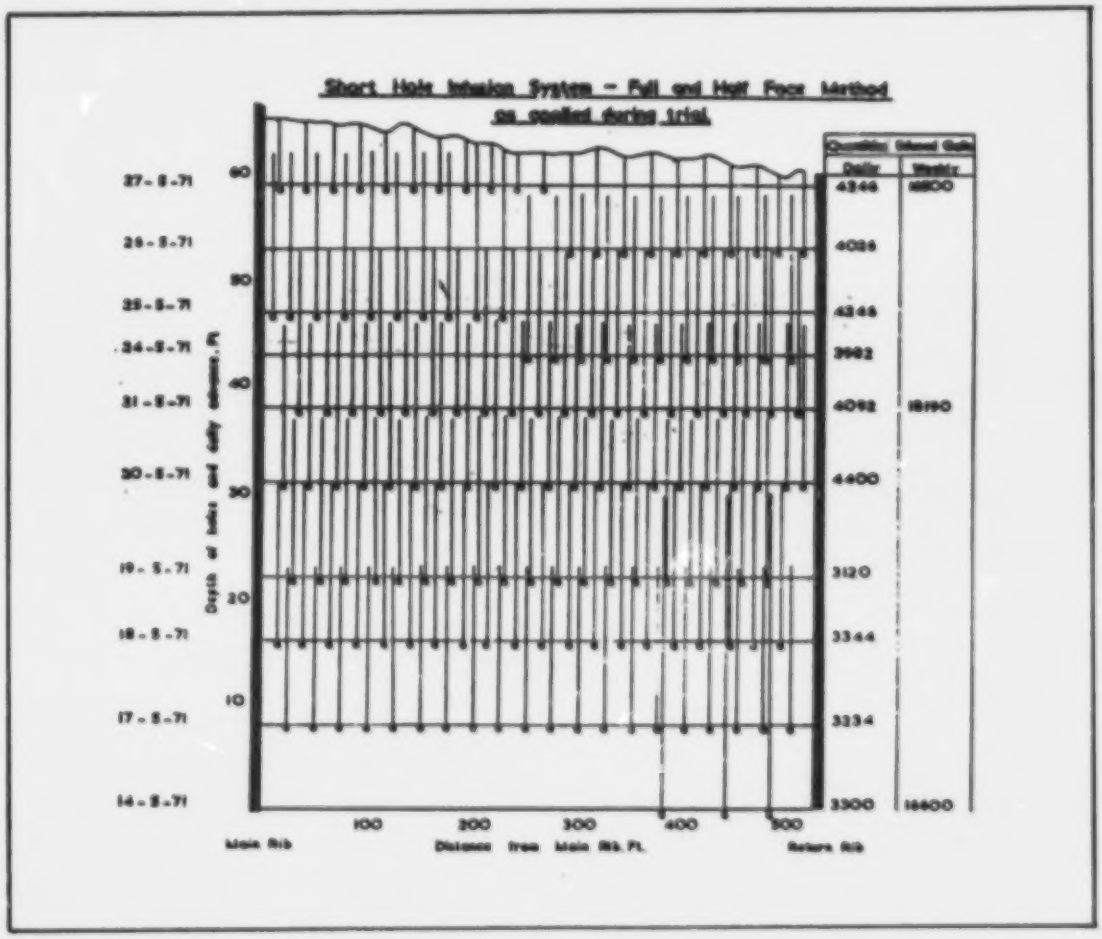


FIGURE 6-2
HOLDITCH COLLIERY, PLAN OF INFUSION TEST AREA WITH LOCATION OF HOLES

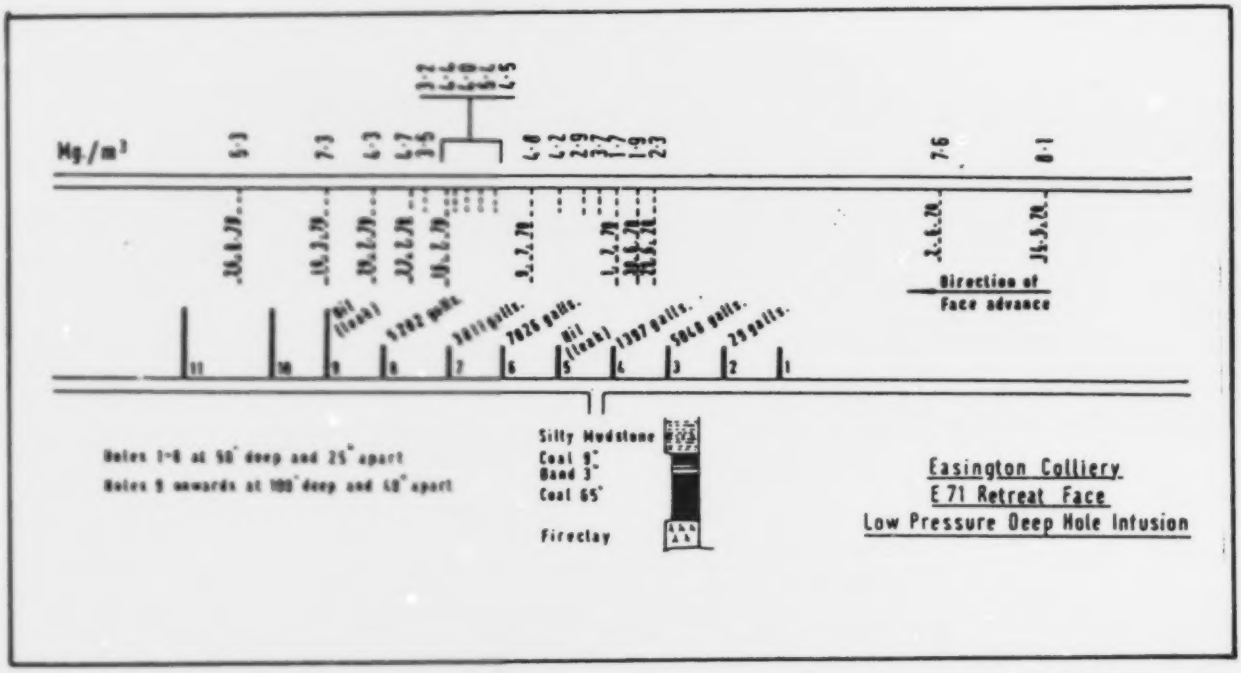


FIGURE 6-3
EASINGTON COLLIERY PLAN OF RETREAT PANEL WITH INFUSION HOLE LOCATIONS

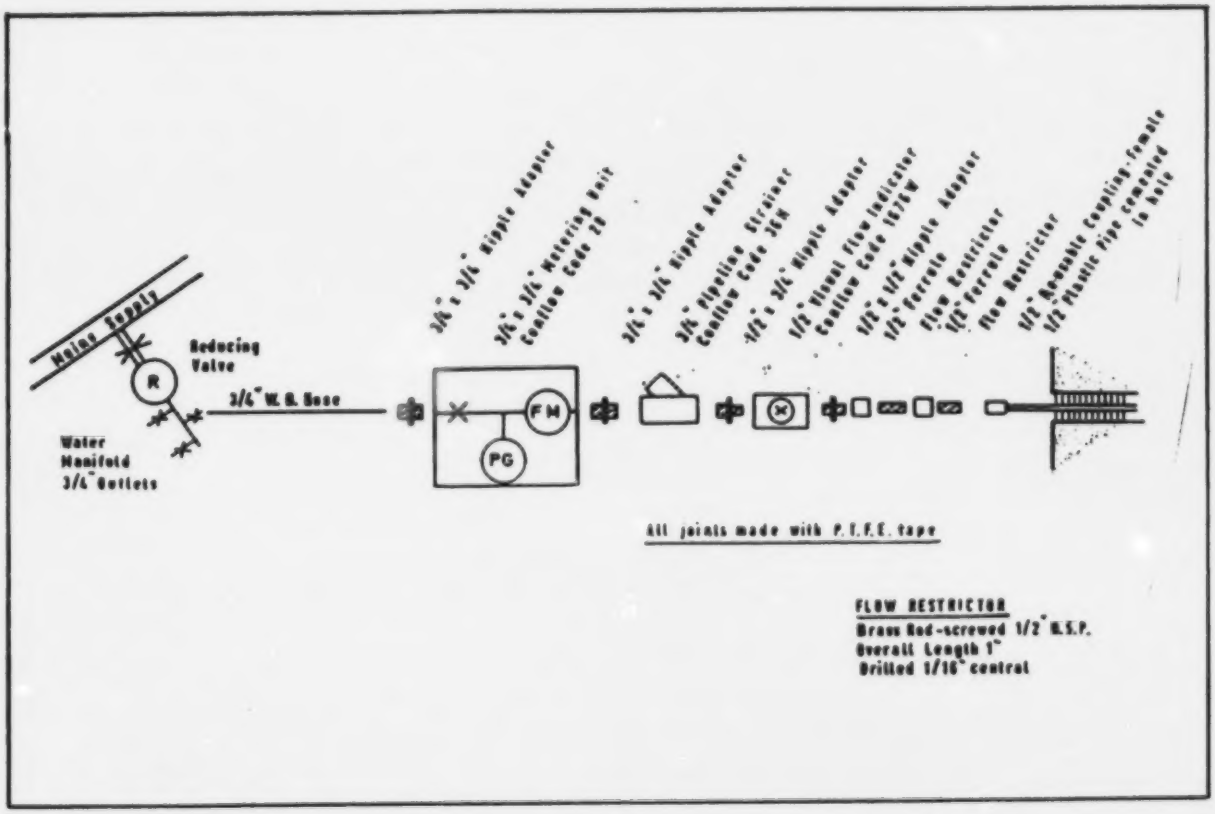

Mains Supply
Reducing Valve
R
3/4" W. S. Base
Water Manifold 3/4" Outlets
3/4" x 3/4" Nipple Adaptor
3/4" x 3/4" Metering Unit Coalbrook Code 25
3/4" x 3/4" Nipple Adaptor
3/4" Pipeline Strainer Coalbrook Code 3548
3/4" x 3/4" Nipple Adaptor
1/2" Visual Flow Indicator Coalbrook Code 1673/W
1/2" x 1/2" Nipple Adaptor
1/2" Terrain Flow Restrictor
1/2" Terrain Flow Restrictor
1/2" Hosetail Coupling, female
1/2" Plastic Pipe connected to hole
FM
PG
All joints made with P.T.F.E. tape
FLOW RESTRICTOR
Brass Rod-screwed 1/2" B.S.P.
Overall Length 1"
Drilled 1/16" central

FIGURE 6-4
DIAGRAM OF INFUSION HOLE CONNECTION SYSTEM, EASINGTON COLLIERY

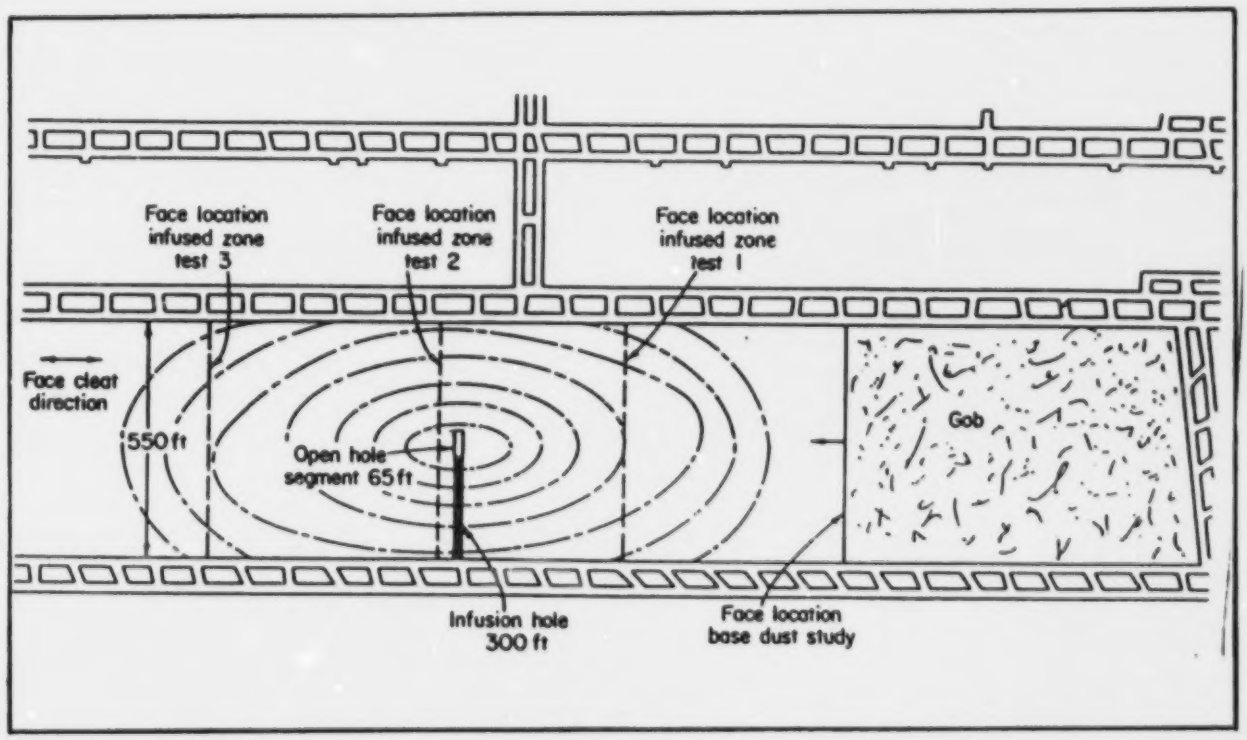

Face location infused zone test 3
Face location infused zone test 2
Face location infused zone test 1
Face cleat direction
550 ft
Open hole segment 65 ft
Gob
Infusion hole 300 ft
Face location base dust study

FIGURE 6-5
LOWER SUNNYSIDE SEAM, PLAN OF RETREAT PANEL
WITH INFUSION HOLE LOCATION

SECTION 7

IMPLEMENTATION

7.1 INTRODUCTION

A good case exists for testing, development and early implementation of water infusion techniques for the Sydney Coalfield. Production from the field was 2.3 million tonnes saleable coal in 1984 and is planned to expand to 3.8 million tonnes by 1987 and to 7.0 million tonnes within the decade. All the new production will come from highly mechanized longwall faces where the potential for dust problems will exist. The most modern applicable mining systems will undoubtedly be installed together with state-of-the-art dust suppression systems at the shearer and elsewhere. Observation of recent U.S. longwall installations and modern European longwall mining practice, indicates that present dust suppression techniques can in many cases be usefully augmented by water infusion. Implementation of water infusion in existing operations would facilitate the rapid application of tested procedures in new collieries as they open up.

The Sydney Coalfield is a virgin area as far as water infusion is concerned. Almost no firm data exist upon which to begin to evaluate the infusibility of the coal, there is an absence of data regarding the sources of dust at the face and the effects of moisture on the structural integrity of the roof and floor remain to be examined. A comprehensive program of research and development is required to provide basic information which could lead to substantial reductions in the hazard from dust.

This section of the report presents a discussion of the topics that will have to be addressed prior to full scale use of water infusion.

7.2 TESTING

Examination and analysis of the existing conditions in the workings should preceed detailed laboratory and in situ testing. The examination of conditions should include:

- detailed dust source survey
- geological mapping of cleat and joint patterns
- mineralogical examination of roof and floor materials and mapping of variations in mineralogy with particular reference to swelling clays
- examination of fresh cleat planes for adherent coal or mineral dust and moisture
- location of stress relief zone around openings and location of abutment pressure zone
- examination of the extent of fissuring related to stress relief around workings.

Laboratory work required in testing may include:

- coal moisture analysis on samples from the face, rib and drill cores
- capilliary rise tests on crushed coal at various sizes and with a range of surfactant additives
- retained moisture measurements on crushed and core samples which have been soaked in water containing a range of surfactant additives.

In situ testing will be required to estimate appropriate pressures and flow rates. These tests should be combined with trials of hole sealing systems, pumping equipment, flow and pressure monitoring devices and additives if laboratory results warrant their use. The orientation of test holes should be varied to allow evaluation of any anisotropic permeability.

Existing drilling equipment in Sydney mine should be evaluated to assess its suitability for water infusion holes. The very long holes required to infuse

advancing faces from adjacent gates may present special problems and require special equipment. It is possible that long hole drilling trials will be necessary.

The potential for methane release from long holes should not be overlooked and precautions should be taken to contain or safely divert any gas. This gas drainage, if it occurs in substantial quantities may prove to be an added advantage to infusion.

7.3 RESEARCH AND DEVELOPMENT

The topics identified in the previous paragraphs present some opportunities for research and development. Laboratory work and data collection activities are considered important preliminary activities which should be addressed in conjunction with a plan for field trials. The majority of the work and expense required however lies in actually performing the trials.

Close cooperation with the management and engineering staff of CBDC should enable much of the necessary work to be undertaken within the framework of the CBDC organization at little marginal cost to operations.

Specific areas where research and development outside the CBDC organization may be more appropriate are:

- development of locally produced self-sealing hydraulic packer for use in short holes, this work would involve the construction of expandable hoses and could profitably be conducted in conjunction with a hose manufacturer;
- laboratory testing of wetting agents, depending on the availability of laboratory time and personnel, this work could be suitably addressed as a small scale project at a university, perhaps by a research assistant/graduate student;
- telemetry control and monitoring of infusion pressures and flow rates, this work could be approached simply as an auxiliary input to existing

mine instrumentation systems but would probably benefit from independent examination until prototype gauges and controls have been tested and proven in the working environment and the instrumentation requirements have been clearly identified. The technology for digital data acquisition, storage, analysis and display is fully capable of handling the information likely to be generated but suitably reliable transducers for use underground may require some development work.

These research and development topics have been the subject of considerable work in Europe. It is possible that an entire set of infusion equipment could be purchased from foreign sources and successfully applied in the Sydney coalfield. This approach is regarded as unsatisfactory if in the long run the intention is to apply water infusion in several new mines. The differences in infusion characteristics from seam to seam and even from face to face would indicate that for widespread success, there should be a concentrated effort to develop Canadian expertise in the field.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

1. Geological factors which affect the porosity and permeability of the coal control the infusibility of a particular location in the seam. The most significant effects are due to the cleat in coal, other fracture systems present and the existence of low permeability rock bands in the seam.

2. The composition of the roof and floor strata and their response to wetting will determine the impact of infusion on strata control. Large fractures or joints in the roof which align with fractures in the coal could conduct significant amounts of water into the roof strata. This would have the minimum impact of reducing the quantity of water available for dust inhibition in the coal and the maximum impact in adverse conditions of severely damaging the integrity of the roof which may produce a serious hazard.

3. There are some indications that bright coal has a higher fracture permeability than dull coal. The effect of this may be that infusion of water is easier but due to the hydrophobic nature of most bright coals, actual wetting of the coal may not occur to the extent necessary to inhibit dusting.

4. Infusion through short holes drilled from the face is the proven technique for use in advancing longwall panels. At the Lingan mine it may be possible to drill long holes parallel to the advancing faces from the adjacent intake road of the preceeding panel. This long hole remote technique requires testing to ensure that an adequate water seal can be established and maintained through the rib pillar.

5. Infusion through long holes drilled from the roads is a proven technique for use in retreat longwalls. The Prince mine presents ideal geometry for this method of water infusion.

6. Water infusion has been shown to effectively inhibit the generation of respirable dust at mechanized longwall installations. Infused water quantities varying from 1 - 3% of the coal mined have been found to be achievable in many mines in Europe and the USA and are sufficient to cause up to 70% reductions in the concentration of respirable dust.

7. Water infusion in conjunction with conventional water spray systems, is in use in 92% to 98% of the collieries in West Germany where regulations require the use of water infusion procedures.

8. Larger size dust particle concentrations can be reduced by the use of water infusion resulting in improved visibility and comfort for face workers.

9. The effect of water infusion on the release of methane is to displace gas from and to inhibit flow through completely infused zones. Where alternate paths are open to the gas, it will continue to migrate into the workings at a different place and possibly at a different time. The changed flow pattern might be advantageous if gas concentrations could be lowered by this means.

10. The use of surfactant additives in the infusion water may improve the infusibility of the coal and decrease the production of dust. Surfactants should be carefully evaluated before use as they can also adversely affect the infusion process.

11. Infusion is carried out at a wide range of pressures and flow rates. Selection of appropriate infusion pressures in necessary to achieve the desired effect without damaging the roof or floor. Pressures vary

from mine supply pressure (typically 2,000 kPa) to very high pressure delivered by infusion pumps (up to 50,000 kPa). Selection of appropriate pressure also depends on the flow required to obtain the necessary quantity of infused water in available time.

12. Infusion from the roads can be conducted in some coals over long periods of time (days to months) at pressures of 1,500 to 3,000 kPa.

13. Infusion from the face is frequently conducted at pressures of 10,000 kPa and higher for short periods of time (less than one shift).

14. Drilling equipment normally available on any operating mine can be used effectively and economically to drill water infusion holes. Careful set up is required on long holes.

15. Precautions should be taken to ensure that methane produced from infusion holes is safely disposed of, into a collection system if necessary.

16. Pumps for use in water infusion are essentially similar to those used to power hydraulic equipment in coal mines.

17. Short infusion holes are effectively sealed during infusion by the use of self-inflating hydraulic packers. This equipment is widely used in Europe.

18. Long infusion holes are efficiently sealed with a cement grout.

19. The manpower required for short hole infusion from the face is approximately twice that required for infusion from the roads.

20. Infusion from the face may interfere adversely with production and maintenance activities.

21. Infusion from the roads does not interface with other activities since it is conducted well in advance of the main working areas.

22. Productivity may be enhanced by the use of water infusion if a face which without infusion operates close to or above the statutory dust levels at low production can be brought into compliance at full production.

8.2 RECOMMENDATIONS

1. A research and development program be conducted to fully evaluate the benefits of water infusion as a means of dust control in the mines of the Sydney coalfield.

2. The initial work required to include a detailed dust source survey at a working face, detailed geological examination and mapping of coal fracture patterns and mineralogical examination of the roof and floor.

3. Laboratory test work to determine the wettability of the coal and its inherent moisture be carried out in conjunction with the survey and mapping.

4. In situ testing of water infusion procedures be designed and performed to provide data on equipment performance and coal infusibility at a range of pressures. These tests should be conducted in a non-producing area.

5. A full scale trial of water infusion, designed on the basis of information obtained through the research program be implemented and carefully monitored.

6. The results of the trials be evaluated and water infusion implemented on a regular basis if substantial benefits can be obtained at acceptable cost.

7. As much as possible of the data collected be published together with details of the operating conditions, infusion procedures and results. High quality research, properly written up is in short supply for water infusion.

8. Opportunities exist for development of water infusion equipment which can be produced in Canada. When infusion trials have been completed and if implementation goes ahead in several mines, the technical and economic merits of equipment development in conjunction with manufacturers should be evaluated.

APPENDIX A

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APPENDIX B

POROSITY AND PERMEABILITY DATA

OFF SHORE BOREHOLE P-6 PRINCE MINE

CORE LABORATORIES – CANADA LTD.

COMPANY CAPE BRETON DEVELOPMENT CORPORATION
WELL CAPE BRETON SELECTED SAMPLES HOLE P-6
LOCATION

FORMATION
ANALYSTS MH JB RG

PAGE 2 of 2
FILE 7004-91096
DATE 79 11 29

CORE ANALYSTS RESULTS

Sample Number	Depth Metres (m)	m Rep.	Sample Length m	Permeability to Air Millidarcys mD Max.	mD 90°	mD V	Perm. x m	Porosity	Porosity x m	Density: kg/m³ Bulk	Density: kg/m³ Grain	Residual Saturation (Fraction of Pore Volume) Oil	Residual Saturation (Fraction of Pore Volume) Water	Visual Examination
P6 j-1	726.00-26.50	0.16	0.12	9.39	9.39	3.80	1.502	0.149	0.024	2260	2650	-	-	
j-2	728.50-29.00	0.17	0.15	4.44	4.44	0.41	0.755	0.135	0.023	2290	2650	-	-	
j-3	731.60-32.10	0.16	0.13	16.9	16.0	2.11	2.704	0.139	0.022	2310	2690	-	-	
j-4	733.50-34.10	0.17	0.14	39.9	36.0	20.9	6.783	0.141	0.024	2320	2700	-	-	
j-5	736.40-36.90	0.17	0.15	60.5	57.8	18.7	10.285	0.169	0.029	2300	2770	-	-	
j-6	738.90-39.40	0.15	0.12	38.4	36.3	14.9	6.144	0.149	0.024	2290	2690	-	-	
j-7	741.20-41.70	0.17	0.14	16.9	14.7	4.08	2.873	0.148	0.025	2270	2660	-	-	
j-8	743.90-44.30	0.14	0.11	19.8	19.4	7.43	2.772	0.158	0.022	2250	2670	-	-	
j-9	(NO DATA)	0.15	0.11	124.	117.	21.4	18.600	0.155	0.023	2290	2710	-	-	
-10	750.30-50.80	0.16	0.12	23.8	22.8	10.6	3.808	0.123	0.020	2340	2670	-	-	
-11	754.60-55.10	0.16	0.14	0.96	0.95	0.20	0.153	0.114	0.018	2380	2680	-	-	
-12	758.80-59.30	0.17	0.15	2.11	1.94	0.67	0.359	0.118	0.020	2340	2660	-	-	
-13	756.30-56.80	0.17	0.14	4.15	4.15	1.33	0.705	0.139	0.024	2300	2660	-	-	

CORE LABORATORIES CANADA LTD.

COMPANY NOVA SCOTIA DEPARTMENT OF MINES
WELL SELECTED SAMPLES
LOCATION

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DATE DEC. 12/78

CORE ANALYSIS RESULTS

Sample Number	Depth Feet	Permeability to Air Millidarcys	Porosity Percent	Residual Saturation		Visual Examination
				% Pore Oil	% Pore Total Water	
H -12b #1	488'6"	20.90	18.1	0.0	20.8	ss vf-f
H -12b-#2	492'0"	34.70	19.1	-	-	ss vf-f
H -12b-#3	493'6"	144.00	18.5	-	-	ss vf-f
H -12b-#4	494'10"	39.20	18.2	-	-	ss vf sl carb
H -12b-#5	496'0"	0.35	11.7	-	-	ss vf-f
H -12b-#6	497'0"	6.18	16.9	-	-	ss vf
H -12b-#7	498'6"	174.00	21.3	-	-	ss vf-f/m
H -12b-#8	500'0"	15.60	19.9	-	-	ss vf-f
H -12b-#9	502'0"	2.00	19.5	-	-	ss vf-f carb
H -12b-#10	503'6"	28.70	19.6	-	-	ss f-m/vf carb incl
H -12b-#11	504'6"	44.30	21.4	-	-	ss vf-f/m
H -12b-#12	505'0"	363.00	22.2	-	-	ss f
H -12b-#13	506'3"	287.00	24.9	-	-	ss f
H -12b-#14	507'6"	12.10	19.4	-	-	ss vf-f
H -12b-#15	508'0"	0.22	10.3	-	-	ss vf-f carb incl
H -12b-#16	492'6"	41.50	19.1	0.0	91.9	ss f
H - #1	965'0"	5.23	18.1	0.0	33.7	ss vf-f
H -12a-#2	970'0"	6.03	17.5	-	-	ss vf-f
H -12a-#3	974'0"	1.94	15.8	-	-	ss vf
H -12 -#1	945'0"	0.22	11.4	0.0	5.5	ss vf
H - 2 -#1	2713'2"	0.15	10.2	5.1	5.1	ss vf
H -12a-#4	977'6"	1.91	16.4	-	-	ss m-c/f

OFF SHORE BOREHOLES H-12, H-12A, H-12B
PRINCE MINE

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COMPANY CAPE BRETON DEVELOPMENT CORPORATION
WELL SELECTED SAMPLES
LOCATION

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ANALYSTS TS DH

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CORE ANALYSIS RESULTS

Sample Number	Depth-Metres (m)	m Rep.	Permeability to Air Millidarcys Horizontal	Permeability to Air Millidarcys Vertical	Porosity	Porosity x m	Residual Saturation (Fraction of Pore Volume) Oil	Residual Saturation (Fraction of Pore Volume) Water	Grain Density kg/m³	Visual Examination
1	PM-25-1	-	0.01	0.03	0.047	-	-	-	2750	ss vf f shy fest
2	PM-25-2	-	0.02	0.01	0.069	-	-	-	2720	ss vf f
3	PM-25-3	-	0.02	0.05	0.083	-	-	-	2720	ss vf f
4	PM-25-4	-	-0.01	0.01	0.054	-	-	-	2770	ss vf f sl shy
5	PM-26-5	-	0.12	1.07	0.090	-	-	-	2720	ss vf f
6	PM-26-6	-	0.04	0.12	0.097	-	-	-	2690	ss vf f carb bks
7	PM-27-7	-	0.10	0.10	0.097	-	-	-	2710	ss vf f

PM-25 [total length of hole - 25.5 ft] - roof hole
N 35,180
W 53,325

PM-26 [total length of hole - 25.75 ft) - roof hole
N 36,970
W 53,600

PM-27

CORE LABORATORIES - CANADA LTD.

COMPANY CAPE BRETON DEVELOPMENT CORPORATION
WELL SELECTED SAMPLES
LOCATION PM-23

FORMATION
ANALYSTS SA KK TS

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DATE 1979 05 29

CORE ANALYSIS RESULTS PM-23

Sample Number	Depth-Metres (m)	m Rep.	Permeability to Air Millidarcys	Permeability x m	Porosity	Porosity x m	Residual Saturation (Fraction of Pore Volume) Oil	Residual Saturation (Fraction of Pore Volume) Water	Grain Density kg/m^3	Visual Examination
1			0.02		0.074				2730	ss vf f sl lmy carb incl
2			0.05		0.086				2710	ss vf f sl lmy carb incl
3			0.14		0.071				2730	ss f lmy sl carb sl shy
4			0.03		0.081				2730	ss vf f lmy carb incl sl shy

PM-23 [total length of hole - 20.2 ft] - roof hole
N 32 974
W 52 952

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CORE LABORATORIES, CANADA LTD.

COMPANY [redacted] BRETON DEVELOPMENT CORPORATION
WELL [redacted] BRETON SELECTED SAMPLES
LOCATION [redacted] [redacted]NATION
[redacted]ALYSTS TS SA

PAGE [redacted]
FILE [redacted]30
DATE [redacted]/09

CORE ANALYSIS RESULTS

Sample Number	Depth Metres (m)	m Res.	Sample Length m	Permeability to Air Millidarcys mD Max	mD 90°	mD V	Perm. x m	Porosity	Porosity x m	Density : kg/m³ Bulk	Grain	Residual Saturation (Fraction of Pore Volume) Oil	Water	Visual Examination
PM24-1A				0.04		0.04		0.103			2760			ss vf fest heavy minerals
PM24-1B				0.02		0.04		0.086			2760			ss vf fest heavy minerals
PM24-2A				0.10		0.09		0.114			2770			ss vf fest heavy minerals
PM24-2B				0.13		0.11		0.102			2770			ss vf fest carb heavy miner
PM24-3A				0.12		0.09		0.111			2770			ss vf fest carb bands heavy minerals
PM24-3B				0.07		0.07		0.095			2770			ss vf fest carb heavy minerals
PM24-4A				0.18		0.16		0.108			2750			ss vf fest heavy minerals
PM24-4B				0.19		0.19		0.120			2750			ss vf fest carb bands heavy minerals
PM24-5A				0.05		0.04		0.096			2760			ss vf fest sl shy heavy minerals
PM24-5B				0.08		0.05		0.102			2760			ss vf fest heavy minerals
12-5-4A				0.02		0.02		0.040			2710			ss vf sl shy v sl lmy
12-5-4B				0.08		0.09		0.050			2710			ss vf sl shy v sl lmy

PM-24 [Total length of hole - 21.2 ft] - roof hole
N 34,322
W 53,370

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QRM-1075

CORE LOG

page ../3

Date June 22, 1979

INTERVAL	THICKNESS	ROCK TYPE	COLOR	DESCRIPTION	DIP
		Permeability ~~To Air~~ Millidarcys	Porosity %	-Samples removed for Porosity and Permeability Measurements	
27- 30"	PM-25-1				
69- 72"	PM-25-2				
90- 92"	PM-25-3				
106-109"	PM-25-4				
125-128"	PM-25-5				
162-164"	PM-25-6				
184-187"	PM-25-7				
				Note:-	
				Benezedine Test performed on immediate roof.	
				Test negative.	
				Core stored: Point Edward	
Note:					
76- 79")	Samples taken				
149-152")	for office				
206-210")	Reference.				
	F.M.I.				

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COMPANY CAPE BRETON DEVELOPMENT CORPORATION
WELL CAPE BRETON SELECTED SAMPLES
LOCATION
FORMATION
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DATE 79 12 31

CORE ANALYSIS RESULTS

Sample Number	Depth-Metres (m)	m Rep.	Permeability to Air Millidarcys	Permeability x m	Porosity	Porosity x m	Residual Saturation (Fraction of Pore Volume) Oil	Residual Saturation (Fraction of Pore Volume) Water	Grain Density kg/m³	Visual Examination
1A	Horizontal Perm.	-	-0.01	-	0.036	-	-	-	2810	ss f m c pbls sl shy pyr
1B	Vertical Perm.	-	-0.01	-	0.038	-	-	-	2840	ss f m c pbls pyr
2A	Horizontal Perm.	-	-0.01	-	0.010	-	-	-	2630	ss vf f sl carb shy
2B	Vertical Perm.	-	-0.01	-	0.010	-	-	-	2620	ss vf f sl carb shy
3A	Horizontal Perm.	-	-0.01	-	0.038	-	-	-	2700	ss vf f sl shy
3B	Vertical Perm.	-	-0.01	-	0.034	-	-	-	2690	ss vf f sl shy
4A	Horizontal Perm.	-	0.05	-	0.070	-	-	-	2690	ss vf f
4B	Vertical Perm.	-	0.11	-	0.069	-	-	-	2690	ss vf f
5A	Horizontal Perm.	-	0.02	-	0.041	-	-	-	2680	ss vf f
5B	Vertical Perm.	-	0.05	-	0.046	-	-	-	2670	ss vf f carb sl fest
6A	Horizontal Perm.	-	0.16	-	0.079	-	-	-	2700	ss vf f sl fest
6B	Vertical Perm.	-	0.26	-	0.079	-	-	-	2680	ss vf f

1A & 1B - LINGAN MINE - 5 EAST - Sandstone - roof
2A & 2B - No. 26 - 13 South - Floor
3A & 3B - Lingan Mine - Room & Pillar - floor
4A & 4B - No. 26 - 12 South - 12 South - roof
5A & 5B - Lingan - roof
6A & 6B - Lingan - 1 west - roof

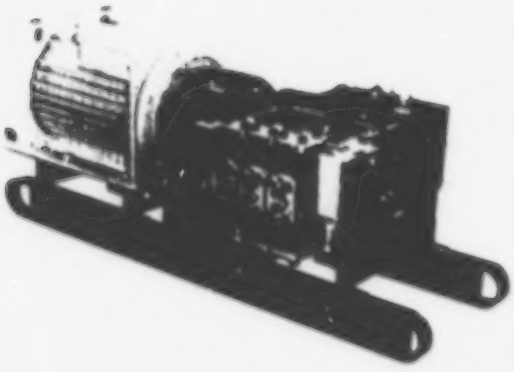
APPENDIX C

EQUIPMENT AND MATERIAL SPECIFICATIONS AND SUPPLIERS

Hauhinco

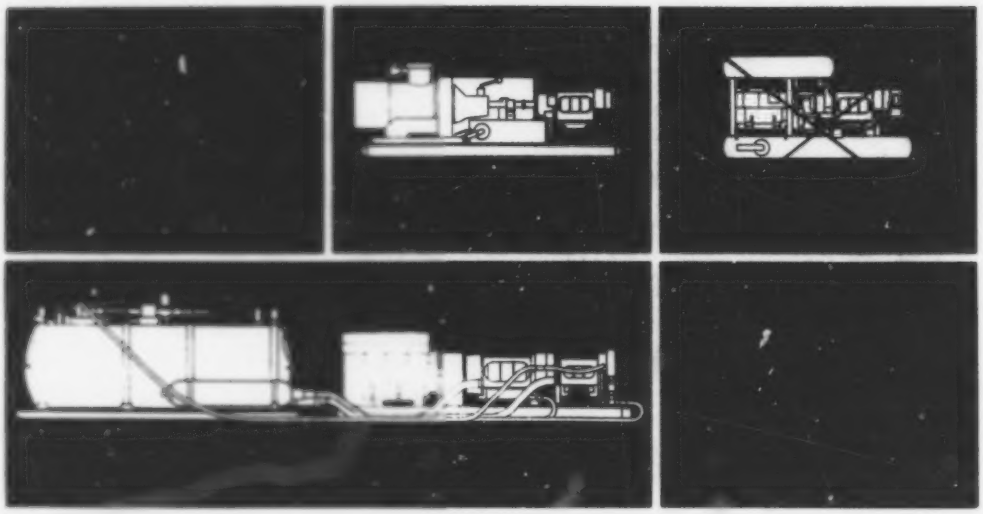
Electric High Pressure Pump EHP-3K 10, 12, 15, 20 *

* Motor rating (kW)



HAUHINCO
HIGH PRESSURE PUMPS

HEART OF THE FACE

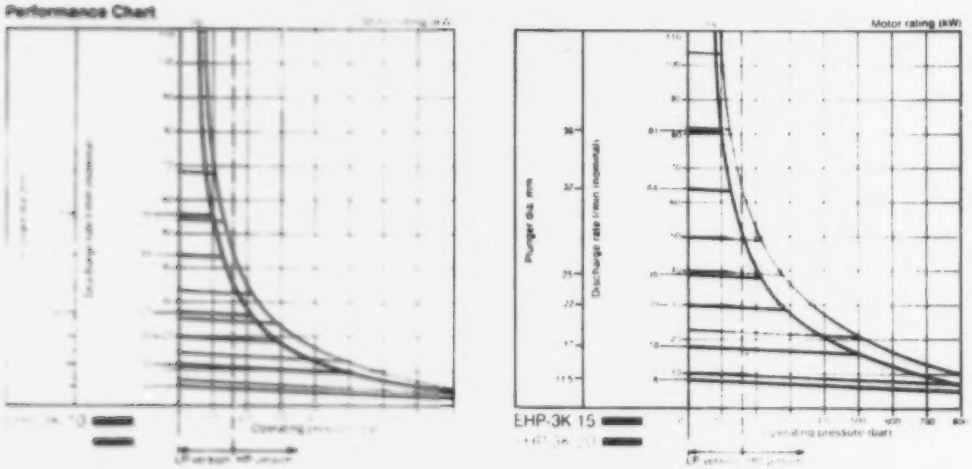


Technical Features

...HP-3K 10, a three-plunger pump ... drive and central lubrication ... with 4 different reduction ... The gear ratio is either ... EHP-3K 15), 2.18 :1 (type EHP-3K 20), and the ... speed of the crank drive ... 660 rpm and ... respectively.

The discharge rate and pressure of the pump ... are easily adjusted by replacing ... and their pump inserts ...

Performance Chart



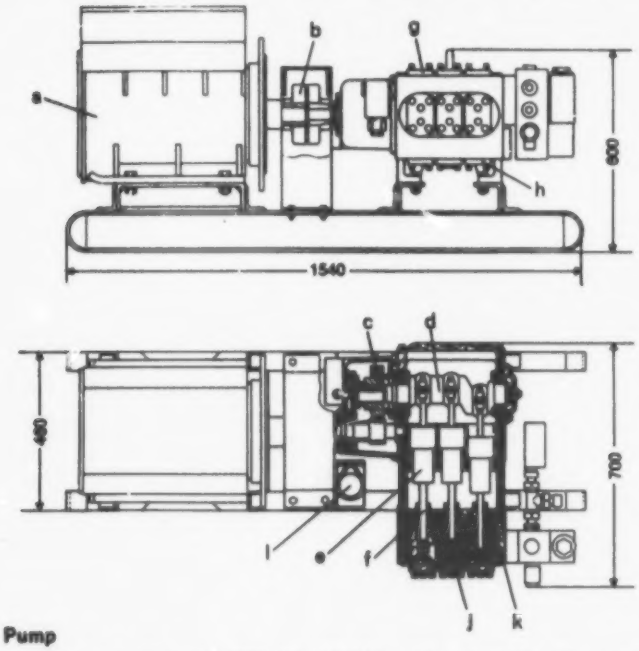
Convenient and reliable

... replacement of plungers and ... inserts. Fast and simple ... ment of plunger seals.

... available at different ... pressure reducers ... safety, and safety through ... monitoring ... circuit, pump inlet flow and ... system.

Hauhinco Maschinenfabrik
G. Hausherr, Jochums GmbH & Co. KG
Zweigertstr. 28/30 · Postfach 10 16 61
D-4300 Essen 1
Tel. 02 01 / 77 10 71 · Telex 8 57 834 hinco

Type EHP-3K 10(12)
with Frame Skid for Closed System



Operation of Pump

The high pressure pump, type EHP-3K 10(12), is a triple plunger pump with crank drive where the driving power of the electric motor a is transmitted via a coupling b and a single reduction gear c to the crankshaft d . The crosshead pistons e operate the three plungers f which perform their alternate suction and delivery strokes. The plungers plunge into the high pressure part j of the pump body k which is provided with the pressure and suction valves g and h .

Reduction gear and crankshaft have a common oil chamber. The pump has a pressure lubrication. The lubricating circuit is electrically controlled by pressure control device i .

Number of revolutions of crank drive (at about 1440 rpm of driving motor):

EHP-3K 10: n = 455 rpm (ratio of reduction gear 3,18:1)
EHP-3K 12: n = 560 rpm (" 2,6 :1)

Stroke of plungers: 40 mm

Liquid Circulation, Control, and Supervision

during operation of pump with the automatic emulsion production plant are described on page 15.

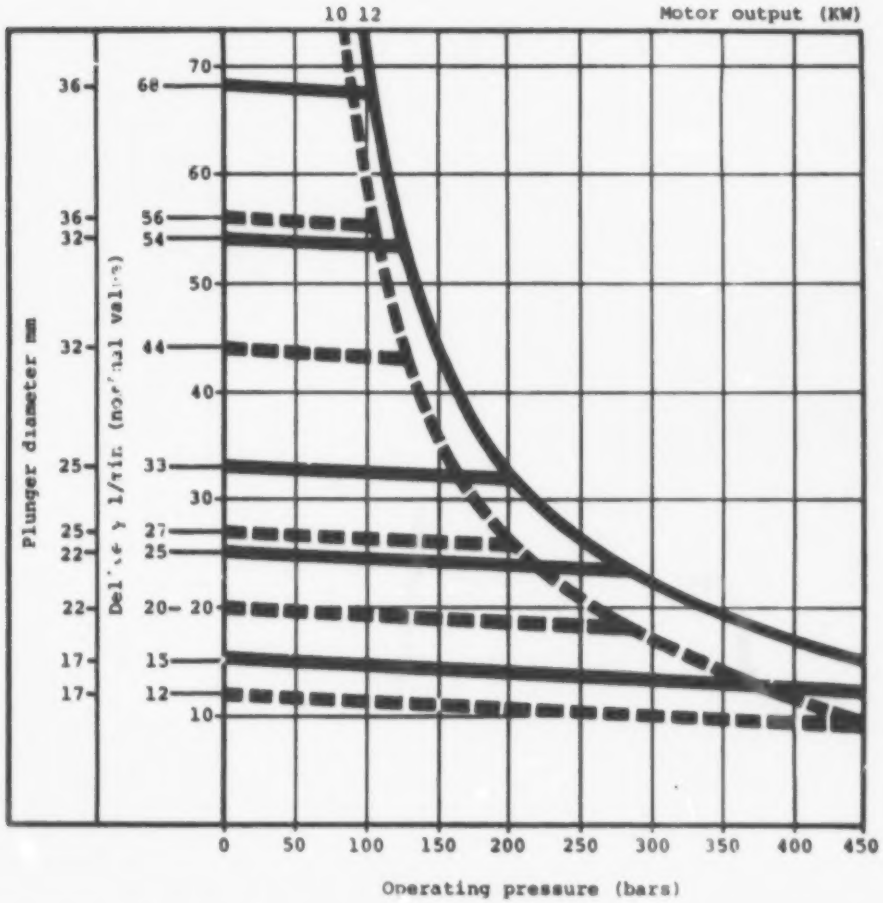
Model with Tubular Skid

Water circulation, control, and supervision during operation of pump in open system are described on page 5.

For Performance Chart see page 4a.

Issue: June, 1977

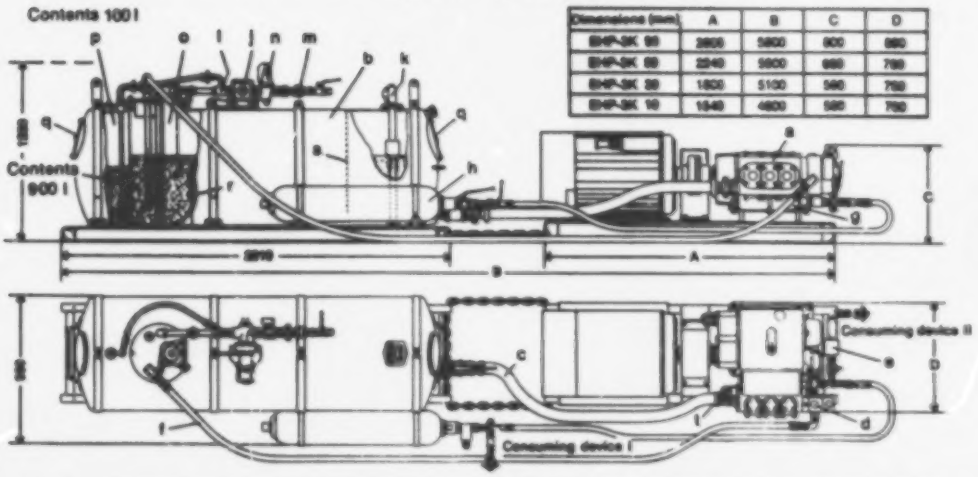
Performance chart: EHP-3K 10(12)



Issue: June, 1977

Automatic Emulsion Production Plant

Type of pump on drawing: EHP-3K 50 (60) (70)



Dimensions (mm)	A	B	C	D
EHP-3K 50	2800	5800	800	880
EHP-3K 60	2240	5800	660	780
EHP-3K 70	1820	5100	560	780
EHP-3K 10	1540	4800	580	780

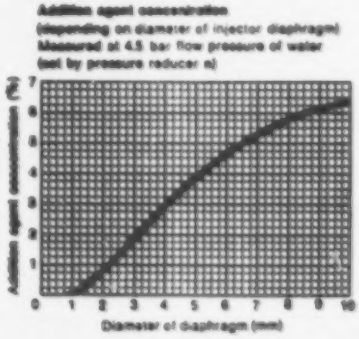
a High pressure pump
b Emulsion production plant
c Suction pipeline
d Pressure control device
e Pressure reducing device
f Return pipeline
g Hydraulic accumulator (2,5 litres)
h Hydraulic accumulator (35 litres)
j Magnetic flow valve
k Level switch
l Injector
m Water purifier
n Pressure reducer
o Magnetic filter to purify the emulsion returning from the consumers
p Reservoir for addition agent
q Sight and cleaning openings
r Partition wall for dirt separation
s Partition wall for air separation
t H.P. control device (if wanted)

The high pressure pump **a** draws the prepared emulsion from the reservoir of the production plant **b** through the suction pipeline **c** . From the pump the pressurised fluid passes via the pressure control device **d** either to consuming device I or via the pressure reducing device **e** to consuming device II, or simultaneously to both consuming devices. (The pressure reducing device or several of these devices can also be mounted clear of the pump on a separate supporting sled.) The pressure control device **d** is set to the operating pressure. If this pressure is attained the device changes over to pressureless circulation. The pump then delivers the liquid through the return pipeline **f** back to the reservoir of the emulsion production plant **b**

The pressure control device is interconnected with the hydraulic accumulator **g** compensating the pressure surges caused by hydraulic change-over. The hydraulic accumulator **h** serves for leakage loss compensation and thus for decreasing the number of change-over-operations.

The emulsion production plant **b** operates as follows: Tap water flows into the reservoir through a magnetic flow valve **j** . If the liquid is at minimum level, the solenoid throughway valve is opened by the level switch **k** , and at maximum level closed. If the tap water supply is cut off the level switch stops the motor. The tap water, in passing through the injector **l** , draws in the addition agent via a diaphragm. The composition of the emulsion can be varied to suit requirements by fitting diaphragms with different diameters.

The emulsion production plant is designed to allow the connection of 2 high pressure pumps.

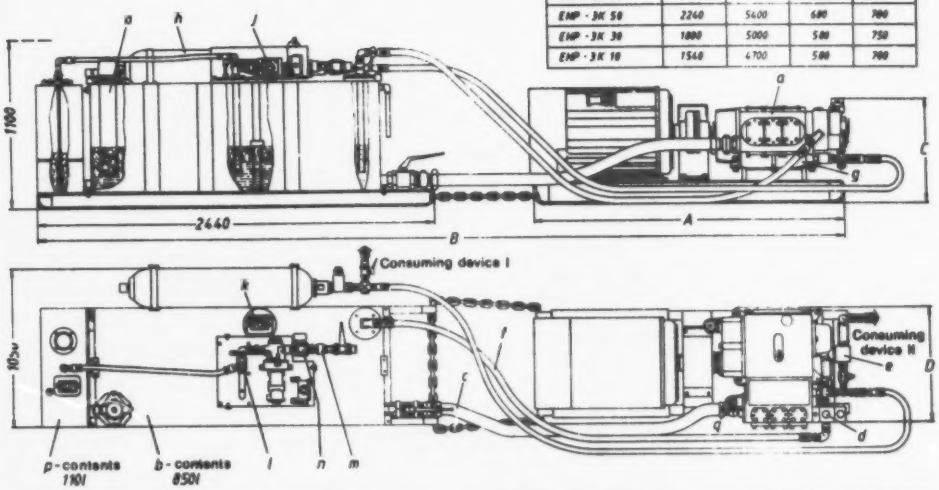

Addition agent concentration
(depending on diameter of injector diaphragm)
Measured at 4,5 bar flow pressure of water
(set by pressure reducer n)
Addition agent concentration (%)
Diameter of diaphragm (mm)

Issue: June, 1977

Automatic Emulsion Production Plant

Type of pump on drawing: EHP-3K 50 (60) (70)

Dimensions (mm)	A	B	C	D
EHP - 3K 90	2480	5800	800	890
EHP - 3K 50	2240	5600	680	780
EHP - 3K 30	1880	5000	580	750
EHP - 3K 10	1540	4700	580	780



a High pressure pump
b Emulsion production plant
c Suction pipeline
d Pressure control device
e Pressure reducing device
f Return pipeline
g Hydraulic accumulator (2.5 litres)
h Hydraulic accumulator (32 litres)
j Magnetic flow valve
k Level switch
l Injector
m Water purifier
n Pressure reducer
o Magnetic filter to purify the emulsion returning from the consumers
p Tank for addition agent
q H. P. control device (if wanted)

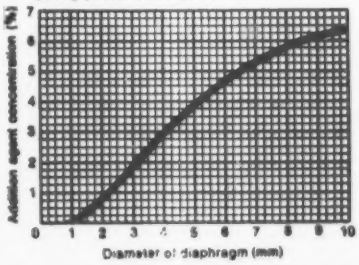
The high pressure pump **a** draws the prepared emulsion from the reservoir of the production plant **b** through the suction pipeline **c** . From the pump the pressurised fluid passes via the pressure control device **d** either to consuming device I or via the pressure reducing device **e** to consuming device II, or simultaneously to both consuming devices. (The pressure reducing device or several of these devices can also be mounted clear of the pump on a separate supporting sled.) The pressure control device **d** is set to the operating pressure. If this pressure is attained the device changes over to pressureless circulation. The pump then delivers the liquid through the return pipeline **f** back to the reservoir of the emulsion production plant **b**.

The pressure control device is interconnected with the hydraulic accumulator **g** compensating the pressure surges caused by hydraulic change-over. The hydraulic accumulator **h** serves for leakage loss compensation and thus for decreasing the number of change-over-operations.

The emulsion production plant **b** operates as follows: Tap water flows into the reservoir through a magnetic flow valve **j** . If the liquid is at minimum level, the solenoid throughway valve is opened by the level switch **k** , and at maximum level closed. If the tap water supply is cut off the level switch stops the motor. The tap water, in passing through the injector **l** , draws in the addition agent via a diaphragm. The composition of the emulsion can be varied to suit requirements by fitting diaphragms with different diameters.

The emulsion production plant is designed to allow the connection of 2 high pressure pumps.

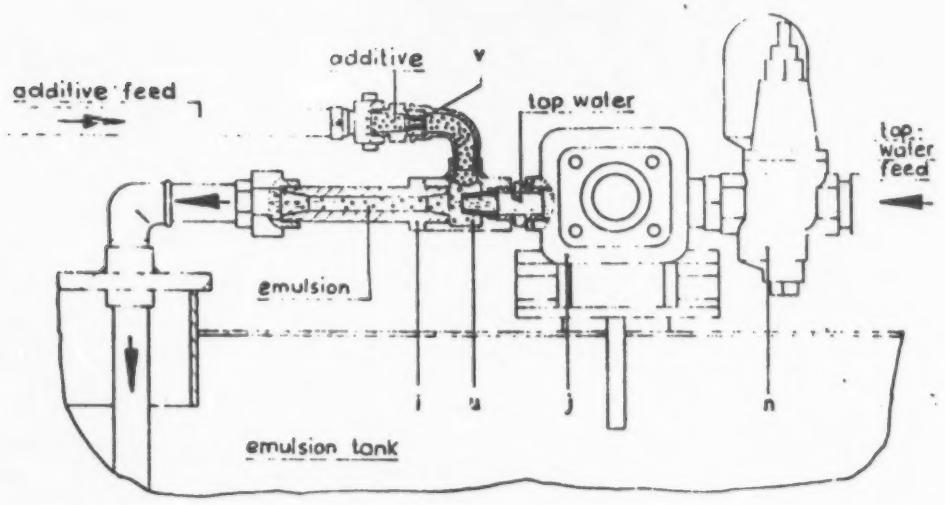
Addition agent concentration
(depending on diameter of injector diaphragm)
Measured at 4.5 bar flow pressure of water
(set by pressure reducer n)



Issue: November, 1981

Automatic Emulsion Production Plant

Supplementary injector description for leaflets 15 and 15a



i - injector
j - solenoid through-valve
n - pressure reducer
u - mixing chamber
v - orifice

The throughflowing tap water produces sub-atmospheric pressure in the mixing chamber (u), which causes the additive to be sucked in. Mixing ratios between 0.5 an 10 % can be adjusted through the installation of appropriate orifices (v) and through water flow-pressure control at the pressure reducer (n), as a function of the additive viscosity. The mixing accuracy is about ± 0.5 % of the additive proportion. Depending upon the pressure adjusted at the pressure reducer, a flowrate of between 100 and 150 litres/min can be achieved with a standard mixing system. It is possible to connect two injectors in a parallel arrangement.

Issue : Nov. 1982

SURFACTANT SUPPLIERS

Supplier	Surfactant
Air Products and Chemicals, Inc. Box 538 Allentown, PA 18105 (215) 398-4911	Surfynol 465
American Cyanamid Co. Berdan Ave. Wayne, NJ 07470 (201) 831-1234	Aerosol GPG Aerosol AY-65 Aerosol MA-80 Aerosol OT-75
BASF Wyandotte Corp. Industrial Chemicals Corp. 1609 Biddle Ave. Wyandotte, MI 48192 (313) 282-3300	Pluronic L-72
Dowell Division of Dow Chemical Box 45828 Houston, TX 77001 (713) 433-3646	F-65
DuBois Chemicals DuBois Tower Cincinnati, OH 45202 (513) 762-6000	D Dust
Emery Industries, Inc. Chemical Specialties Group Box 628 Mauldin, SC 29662 (513) 762-6200	Tryfac 610-K
Finetex Inc. 418 Falmouth Ave. East Paterson, NJ 07407 (201) 797-4686	Gemtex SC-40
GAF Corp. Chemical Products 140 West 51st St. New York, NY 10020 (212) 582-7600	Igepal CO-610
Johnson-March Corp. 3018 Market St. Philadelphia, PA 19104 (215) 222-1411	Compound MR

Supplier	Surfactant
Mona Industries, Inc. 65 East 23d St. Paterson, NJ 07524 (201) 274-8220	Monowet MO-70E
Motomco, Inc. 267 Vreeland Ave. Paterson, NJ 07513 (201) 345-6202	Aquadyne
Preiser Scientific, Inc. Jones and Oliver Sts. St. Albans, WV 25177 (304) 727-2902	Coal Dyne 100
Rohm and Haas Co. Independeance Mall West Philadelphia, PA 19105 (215) 592-3000	CF-54
Scholler Bros., Inc. Collins and Westmoreland Sts. Philadelphia, PA 19134 (215) 739-0900	Product 55
Spartan Chemical Co. 110 North Westwood Ave. Toledo, OH 43607 (419) 531-5551	DC-13
Union Carbide Corp. Chemicals and Plastics 270 Park Ave. New York, NY 10017 (212) 551-3763	Tergitol NPX
Wen-Don Corp. Box 13905 Roanoke, VA 24034 (800) 336-5713	Dustallay

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